FESHM 5031.1 PIPING ENGINEERING NOTE FORM

Prepared by: Terry Tope Preparation Date: June 17, 2011

Piping System Title: LAPD liquid argon purification and filter regeneration piping.

Lab Location: PC4 Lab Location code: 701030125

Purpose of system / System description: To purify liquid argon and regenerate liquid argon filters.

Piping System ID Number:

Appropriate governing piping code: ASME B31.3 - 2010

Fluid Service Category (if B31.3): Category-D / Normal / Category-M / High Pressure
(circle one)

Fluid Contents: Liquid & Gaseous Argon

Design Pressure: 25 psig, 60 psig, 100 psig, and 115 psid.

Design Temperature: liquid argon purification: -303 ^{o}F (87 K), filter regeneration: +482 ^{o}F

Piping Materials: See note.

Drawing Numbers (PID's, weldments, etc.): See note.

Designer/Manufacturer: FERMILAB

Test Pressure: See note.

Test Fluid: pneumatic Test Date: See note.

Statements of Compliance

Piping system conforms to FESHM 5031.1, installation ***is not*** exceptional: Yes / No

Piping system conforms to FESHM 5031.1, installation ***is*** exceptional and has been designed, fabricated, inspected, and tested using sound engineering principles: Yes / No

Reviewer's Signature: Roger Rabehl ROGER RABEHL 10654N Date: 9/1/11

D/S Head's Signature: Date: 9/12/2011

ES&H Director's Signature: NA Date:

(if exceptional)

Director's Signature or Designee: NA Date:

(if exceptional)

Pipe Characteristics

Size: See note for full details. Primary sections are 1" SCH 10 with 3" SCH 10 vacuum jacket and 2" SCH 10 with 5" SCH 10 vacuum jacket.

Length: See note for full details. Approximate piping footprint is 40' x 20'.

Volume: ~ 200 liters

Relief Valve Information

Type: See note for all relief info. Manufacturer:

Set Pressure: Relief Capacity:

Relief Design Code:

Is the system designed to meet the identified governing code? Yes / No

Fabrication Quality Verification

System Documentation

Process and Instrumentation diagram appended? Yes / No

Process and Instrumentation component list appended? Yes / No

Is an operating procedure necessary for safe operation? Yes / No
If 'yes', procedure must be appended.

Exceptional Piping System

If "Yes", follow the requirements for an extended engineering note for Exceptional Piping Systems.

<u>Quality Assurance</u>

List vendor(s) for assemblies welded/brazed off site: No assemblies were fabricated off site.

List welder(s) for assemblies welded/brazed in-house: See note.

Append welder qualification records for in-house welded/brazed assemblies.

See note.

Append all quality verification records required by the identified code (e.g. examiner's certification, inspector's certification, test records, etc.)

See note.

Statements of Compliance for Amendment #1

Prepared by: Terry Tope Preparation Date: June 18, 2012

Piping system conforms to FESHM 5031.1, installation ***is not*** exceptional Yes / No

Piping system conforms to FESHM 5031.1, installation ***is*** exceptional and has been designed, fabricated, inspected, and tested using sound engineering principles: Yes / No

Reviewer's Signature: Roger Rabehl ROGER RABEHL Date: 11/5/12

D/S Head's Signature: [signature] Date: 11/12/2012

ES&H Director's Signature: NA________________ Date: ________
(if exceptional)

Director's Signature or Designee: NA________________ Date: ________
(if exceptional)

Table of Contents

1.0 – GENERAL REQUIREMENTS:

1.1 – System Description:

This note details the liquid argon purification piping associated with the LAPD project. The note covers stainless steel piping that contains liquid argon and operates at -303 ^{o}F. The note also covers stainless steel piping that contains gaseous argon, nitrogen, or a non-flammable mix of argon & hydrogen that operates at temperatures up to 482 ^{o}F for filter regeneration. Associated piping not designed to operate below –20 ^{o}F or above 366 ^{o}F is not detailed in this note.

The documentation has been updated to reflect modifications required for the 2nd run of LAPD. These updates will be treated as an amendment to the original piping engineering note. Updates will be noted by yellow highlighted text.

The vacuum jacketed argon purification piping has been modified to accommodate LBNE 35T connections to the purification system. The connection details are shown on drawings MD-489656 and MD-489654 available in Appendix B.

Conflat flanges have been added on either side of the molecular sieve and oxygen filters to allow for filter removal. To access the conflat flanges edge welded bellows (with restraints) and Marmon flanges have been added to the vacuum jacket. Downstream of the oxygen filter a particulate filter has been added to the piping. The particulate filter is identical to existing filters at the liquid pump suction and the tank liquid return. MD-486264 has been annotated to note these changes.

Two vacuum jacketed bellows sealed cryogenic valves were removed from the piping to use elsewhere. MD-486264 has been annotated to note this change.

A line was added to connect the liquid pump discharge and the tank vapor space to purge vapor from the pump. This line consists of ½" OD ss tubing. The flexibility of this line is documented in section 2.1 and its trapped volume relief sizing is documented in section 2.5.1.

1.2 – Referenced ES&H Sections:

In addition to conforming to the pressure piping standards put forth in ES&H 5031.1, the LAPD purification piping is obligated to conform to the requirements of ES&H 5032 – Cryogenic System Review.

Table 1: B31.3 Piping Summary

Piping Description	Applied Code and Service	Design Pressure	Operating Temperature	Method of Examination	Pressure test
Tank to MV-368[1]	B31.3 Normal	25 psig (40 psid for	-303 ^{o}F	In-process	Pneumatic 29 psig (44

	Fluid	VJ portion)		inspection	psid test for VJ portion)
Tank to MV-367-Ar	B31.3 Normal Fluid	100 psig (114.7 psid for VJ portion)	-303 °F	In-process inspection	Pneumatic 111.5 psig (126.5 psid test for VJ portion)
Tank to condenser	B31.3 Normal Fluid	60 psig (74.7 psid for VJ portion)	-303 °F	In-process inspection	Pneumatic 66 psig (80.7 psid test for VJ portion)
Tank to MV-330-Ar	B31.3 Normal Fluid	100 psig	-303 °F	In-process inspection	Pneumatic 110 psig test
Tank to MV-384-Ar	B31.3 Normal Fluid	100 psig	-303 °F	In-process inspection	Pneumatic 110 psig test
Tank to PSV-377-Ar[2]	B31.3 Normal Fluid	3 psig	-303 °F	In-process inspection	Pneumatic 3.75 psig test
Filter regeneration piping	B31.3 Normal Fluid	100 psig	+482 °F	In-process inspection	Pneumatic 110 psig test
All other LAr purification piping	B31.3 Normal Fluid	100 psig (114.7 psid for VJ portion)	-303 °F	In-process inspection	Pneumatic 126.5 psid test

[1]This section of piping is only pressurized by the LAPD tank vapor pressure and liquid head. The maximum liquid height in the tank is 10 feet such that the head available is 87 lb/ft^3 x 10 ft x 1 ft^2/144 in^2 = 6.04 psi. The maximum vapor pressure in the tank is 3 psig. Thus the total pressure available at the tank bottom relative to atmosphere is 9.04 psid (24 psid for the VJ portion).

[2]This section of piping is only pressurized by the LAPD tank vapor pressure.

1.3 – Flow Schematic and Fabrication Prints:

Appendix A contains the flow schematic in which the relevant portions are highlighted. The valve and instrument list is also found in Appendix A. Appendix B contains the mechanical drawings used to fabricate the piping. These drawings can also be located in the FERMILAB I-DEAS TDM. Unistrut stands were fabricated as needed to support the vacuum jacketed piping.

Both Appendix A and Appendix B have been updated to reflect the changes associated with this amendment.

2.0 – ENGINEERING DOCUMENTATION

2.1 – Thermal Contraction Relief

Without sufficient relief from the thermal contraction induced stress resulting from the cooling down of a section of pipe from 300 K to 87 K, a straight piece of 304 stainless steel pipe will fail. The method for allowing pipe movement involves lengths of braided flexible hoses aligned perpendicular to the axis of pipe movement. The vacuum jacket also contains sections of braided flexible hose to add flexibility at the tank, the liquid argon flowmeter (FT-595-Ar), and at the two filter vessel interfaces.

The flexibility of the pump cool down line was looked at using an ANSYS piping model. The Ansys model details are shown in the next four figures. A maximum thermal stress of 10.1 ksi was computed which is below the 16.7 ksi allowable.

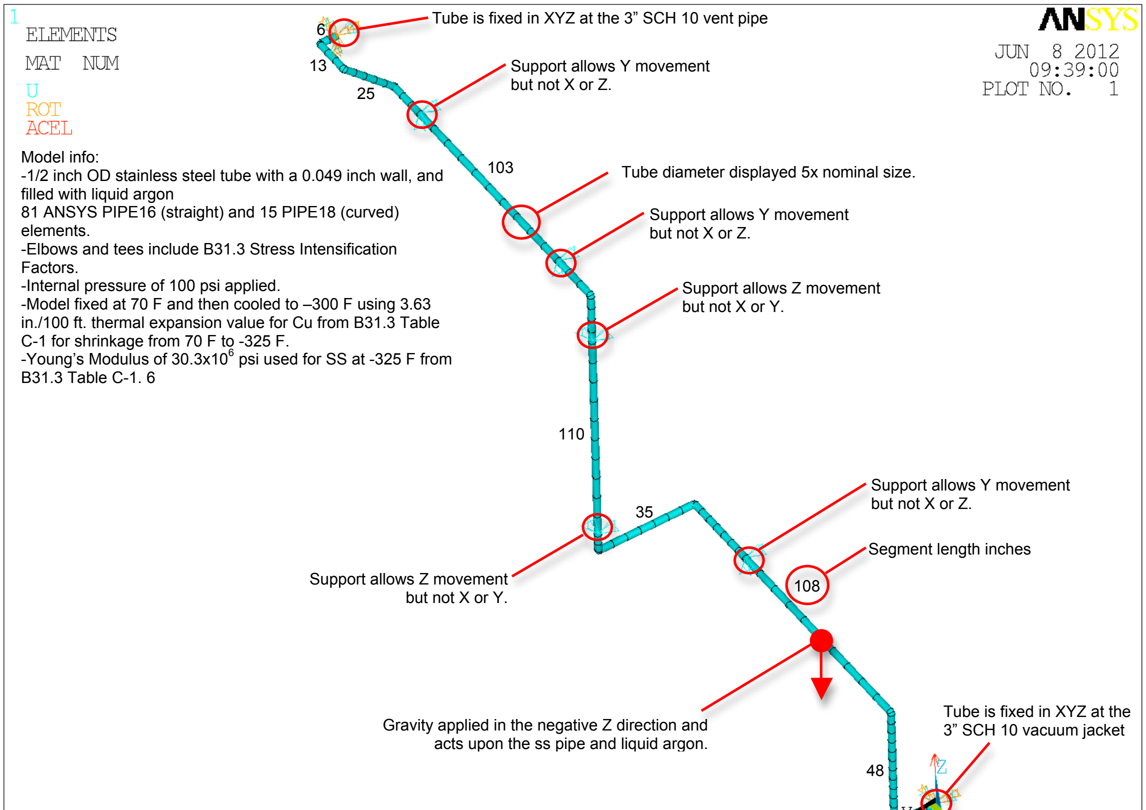


Figure A: Pump cool down piping FEA inputs.

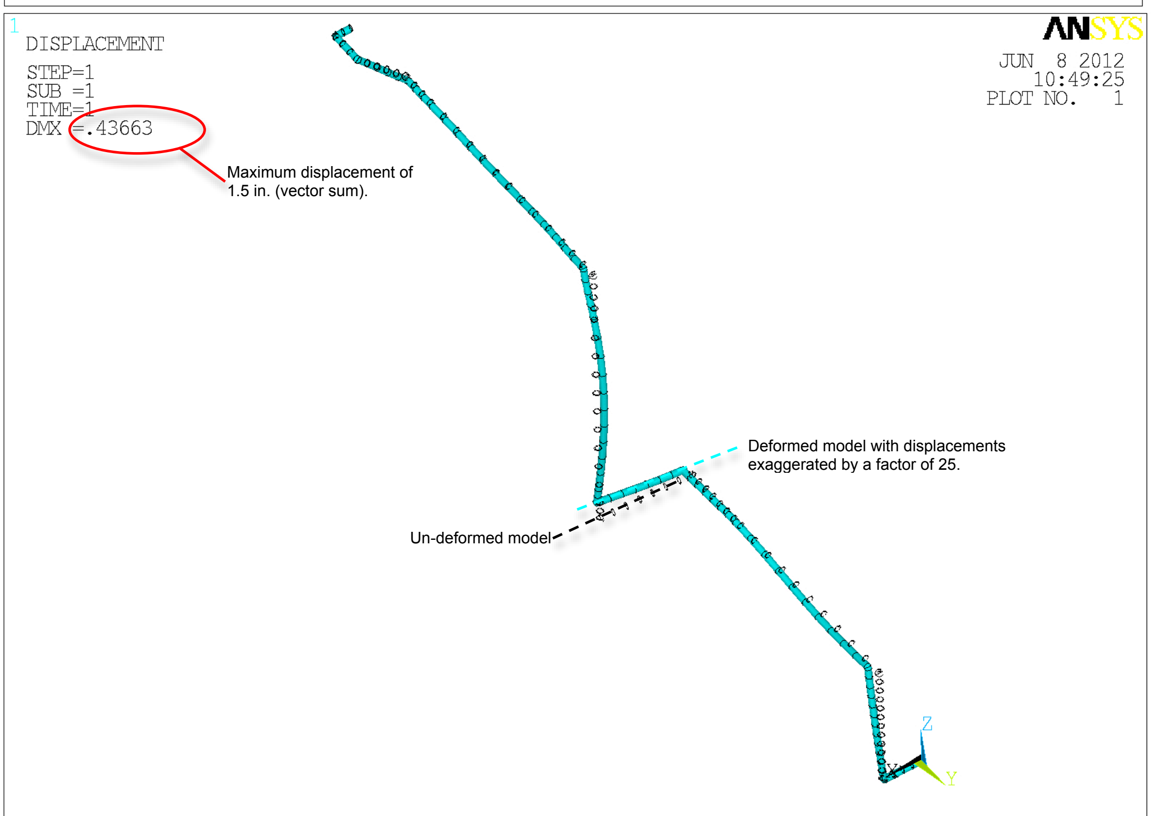


Figure B: Pump cool down piping deformed model.

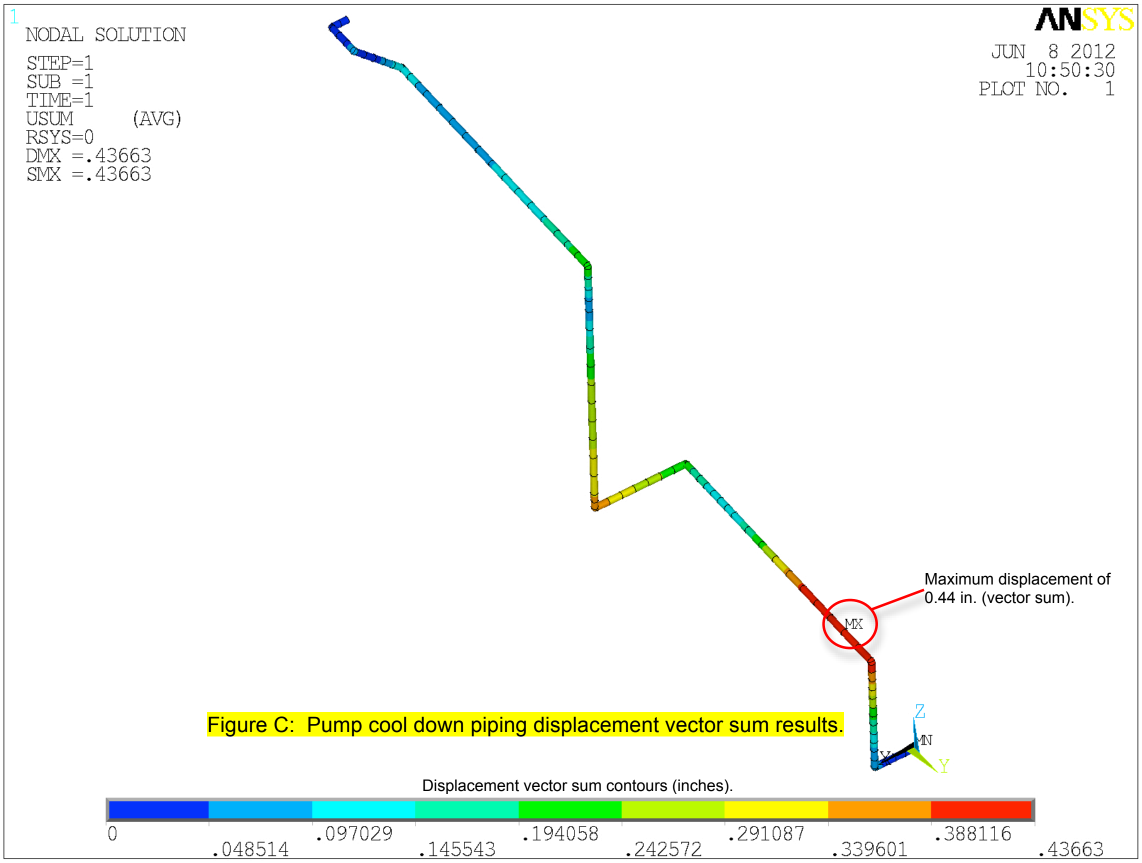


Figure C: Pump cool down piping displacement vector sum results.

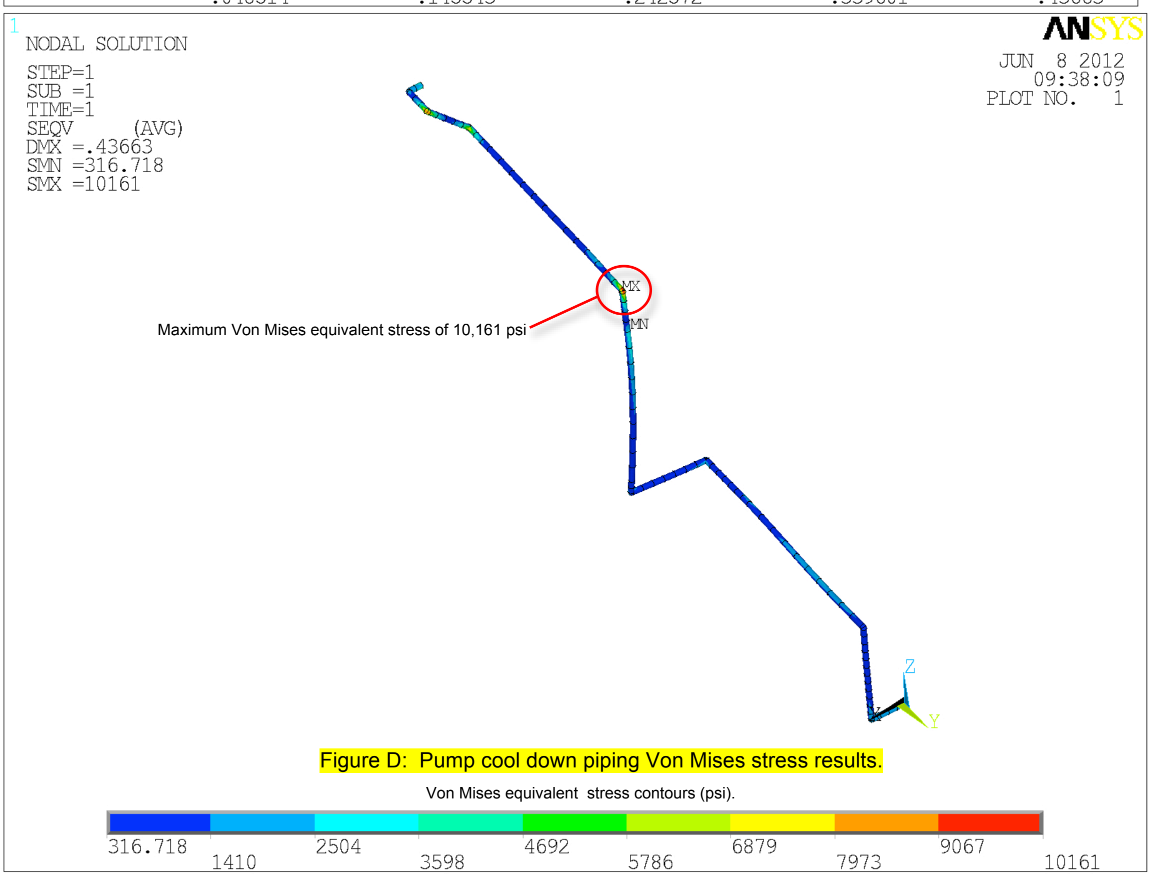


Figure D: Pump cool down piping Von Mises stress results.

2.2 – Charpy Impact Testing Requirement

Appendix D contains a memo dated 12.29.09 which documents testing performed which satisfies the B31.3 impact testing requirements for piping welded at Fermilab and used at temperatures as low as -320 ^{o}F.

2.3 – Pipe Stress Calculations

2.3.1 – Pipe Wall Thickness Calculations

All of the piping in the system has a minimum quality of 304L stainless steel. The allowable stress *S* used for calculation of the minimum wall thickness *t* is taken from B31.3 Table A-1, and is 16.7 ksi for 304L austenitic stainless steel, and contains an additional safety factor of 3.5, which is not part of the safety factor calculated in the table below. Table 2 shows the various pipe sizes used in the LAr purification system piping, the minimum calculated wall thickness for the relevant section pressure, and the resulting factor of safety for the actual pipe/tube installed. The calculation for the minimum wall thickness was done using B31.3 Section 304.1.2 Straight Pipe Under Internal Pressure:

$$t = \frac{PD}{2(SEW + PY)}$$

In this equation, *E* is the quality factor for the pipe or tube and is equal to 1.0 for seamless tube and pipe. *W* is the weld joint strength reduction factor which applies only at elevated temperatures and therefore is equal to 1.0. *Y* is a coefficient from table 304.1.1 and is given as 0.4 for austenitic stainless steels. The maximum design pressure *P* of 115 psid was chosen because the trapped volume reliefs are set at 100 psig.

Table 2. Pipe Thickness Factor of Safety Calculations Under Internal Pressure

Pipe or tube size	Outside diameter *D* inch	Allowable stress *S* psi	Design pressure *P* psid	Required wall thickness *t* in	Actual wall thickness in	Actual wall thickness / required wall thickness ratio
1/8" tube x 0.020" wall	0.125	16,700	115	0.000429	0.035	81.5
1/4" tube x 0.035" wall	0.250	16,700	115	0.000858	0.035	40.8
1/2" tube x 0.035" wall	0.500	16,700	115	0.001717	0.035	20.4
1/2" tube x 0.049" wall	0.500	16,700	115	0.001717	0.049	28.5
1" tube x 0.049" wall	1.000	16,700	115	0.003434	0.049	14.3
1" tube x 0.065" wall	1.000	16,700	115	0.003434	0.065	18.9
1.75" tube x 0.065" wall	1.750	16,700	115	0.006009	0.065	10.8
6" OD tube x 0.120" wall	6.000	16,700	115	0.020602	0.120	5.8
8" OD tube x 0.120" wall[1]	8.000	16,700	3	0.000719	0.120	167.0
1/2" sch 10 pipe	0.840	16,700	115	0.002884	0.083	28.8
3/4" sch 10 pipe	1.050	16,700	115	0.003605	0.083	23.0
3/4" sch 40 pipe	1.050	16,700	115	0.003605	0.113	31.3
1" sch 10 pipe	1.315	16,700	115	0.004515	0.109	24.1
2" sch 10 pipe	2.375	16,700	115	0.008155	0.109	13.4
2" sch 40 pipe	2.375	16,700	115	0.008155	0.154	18.9
3" sch 10 pipe	3.500	16,700	115	0.012018	0.120	10.0
5" sch 10 pipe	5.563	16,700	115	0.019101	0.134	7.0

[1]This section of piping connects the relief valve to the tank and only sees the tank vapor pressure of 3 psig.

2.3.2 – Purity Monitor Branch Connection

The purity monitor vessel has a branch connection that must be checked for proper reinforcement according to 304.3.3 of the Code (MD-466995). The branch connection consists of a 1" SCH 10 pipe intersecting a 6" OD tube run.

There is no reinforcement added so the analysis will include only the excess thickness of the pipes and tubes as reinforcement. The required reinforcement area is given by:

$$A_1 = t_h d_1 (2 - \sin\beta)$$

t_h = the pressure design thickness of the run pipe, 0.0206 inches for the 6" tube (Table 2).

d_1 = effective length removed from the pipe at branch which is the branch outer diameter, 1.315".

β = angle between the axes of the branch and run, 90 degrees for this case.

Thus the required area is

$$A_1 = \quad 0.0206 \times 1.315 \times (2 - \sin\ 90) = 0.02709\ in.$$

The available area is defined as:

$$A_2 + A_3 + A_4 \geq A_1$$

Area A_2 is the area resulting from excess thickness in the run pipe wall:

$$A_2 = (2d_2 - d_1)(T_h - t_h - c)$$

d_2 = half width of the reinforcement zone

= d_1 or $\left(T_b - c\right) + \left(T_h - c\right) + \frac{d_1}{2}$, which ever is greater.

T_b = branch pipe thickness, 0.109 – 0.109 x 0.125 = 0.095375".

c = sum of the mechanical allowances for thread or groove depth, plus corrosion and erosion allowances, zero for this case.

T_h = run pipe thickness, 0.120 – 0.120 x 0.125 = .105".

Thus $\left(0.095375 - 0\right) + \left(0.105 - 0\right) + \frac{1.315}{2} = 0.8579$ which is less than d_1 so

$d_2 = d_1 = 1.315$".

Thus the area resulting from excess thickness in the run is

$$A_2 = (2 \times 1.315 - 1.315)(0.105 - 0.0206 - 0) = 0.11099\ in^2.$$

Area A_3 is the area resulting from excess thickness in the branch pipe wall:

$$A_3 = \quad 2L_4(T_b - t_b - c)/\sin\beta$$

L_4 = height of the reinforcement zone outside of the run pipe

= $2.5(T_h - c)$ or $2.5(T_b - c) + T_r$, whichever is less.

T_r = minimum thickness of the reinforcing ring, 0 for this case without reinforcement.

t_b = the pressure design thickness of the branch, 0.004515", from Table 2.

For L_4,

$$2.5(0.105 - 0) = 0.2625,\ 2.5(0.095375 - 0) + 0 = 0.238438$$

thus L_4 equals 0.238438.

The area resulting from excess thickness in the branch pipe is then

$$A_3 = \quad 2 \times 0.238438 \times (0.095375 - 0.004515 - 0)/\sin 90 = 0.043329\ in^2.$$

Area A_4 is the area of other metal provided by welds and properly attached reinforcement. No credit is being taken for the welds.

$$A_2 + A_3 + A_4 \geq A_1$$
$$0.11099 + 0.043329 + 0 \geq 0.02316$$
$$0.15432 \geq 0.02316$$

The available area sums to 6 times the required area.

2.3.3 – Vacuum Jacket Braided Hose Restraints

The stainless steel braided hoses on the vacuum jacket are each constrained by three threaded rods equally spaced around their perimeter. The hose braid is designed to resist the bellows pressure thrust due to internal pressure. But on the 3 inch larger vacuum jacket hoses the braid does a poor job resisting the pressure thrust due to external pressure. Without additional restraint the hoses will shorten under external pressure putting significant forces on other portions of the vacuum jacket. The threaded rods are sized to resist buckling due to external pressure but still allow the flexible hoses to move laterally. The buckling strength of the threaded rods is analyzed using the classic Euler-column formula where:

$$P_{cr} = \frac{\pi^2 E}{S_r^2} A,\ S_r = \frac{l}{k},\ k = \sqrt{\frac{I}{A}},\ A = \frac{\pi}{4} D^2,\ I = \frac{\pi D^4}{64}$$

P_{cr} = critical column load, lb_f.

E = Young's modulus, 27.5 x 10^6 lb_f/in^2 for stainless steel.

S_r = slenderness ratio, determines if a column is short or long, dimensionless.

A = area of column cross-section, in^2.

D = column diameter, in^2. Equal to the threaded rod minor diameter.

l = length of the column, inches, an effective length equal to the actual length is a conservative value for the fixed-fixed end conditions of the threaded rods.

k = radius of gyration, in.

I = smallest area moment of inertia of the column's cross section, in^4.

The pressure thrust, P_{th}, is calculated by multiplying the area of the hose calculated from its external diameter D_{OD} (the outside diameter of the hose convolutions), and atmospheric pressure.

$$P_{th} = \frac{\pi}{4} D_{OD}^2 \times 14.7 \frac{lb}{in^2}$$

Table 3 summarizes the threaded rod calculations. The safety factor is calculated as three times the critical load per rod (three rods per hose) divided by the pressure thrust that must be resisted.

Table 3. Threaded rod buckling calculations.

Nominal hose diameter	Actual hose outside diameter D_{OD}	Pressure thrust P_{th}	Hose length l	Threaded rod size	Rod minor diameter D	Rod area A	moment of inertia I	Radius of gyration k	Slenderness ratio S_r	Critical load P_{cr} per rod	Safety factor
in	in	lb_f	in	in	in	in^2	in^4	in	-	lb	-
6	7	566	20	1/2-13	0.4001	0.1257	0.0013	0.1000	200	854	4.5
5	6	416	36	1/2-13	0.4001	0.1257	0.0013	0.1000	360	263	1.9
5	6	416	24	1/2-13	0.4001	0.1257	0.0013	0.1000	240	593	4.3
5	6	416	20	1/2-13	0.4001	0.1257	0.0013	0.1000	200	854	6.2
3	3.88	174	20	3/8-16	0.2938	0.0678	0.0004	0.0735	272	248	4.3
3	3.88	174	16	3/8-16	0.2938	0.0678	0.0004	0.0735	218	388	6.7
3	3.88	174	16	3/8-16	0.2938	0.0678	0.0004	0.0735	218	388	6.7
3	3.88	174	12	3/8-16	0.2938	0.0678	0.0004	0.0735	163	689	11.9

2.4 – Piping Components

2.4.1 – Unlisted Components

In B31.3 code, Table 326.1 list Component Standards that define listed components. Components used in the system that do not fall into a category of the B31.3 table or listed components without a definite pressure rating are listed in Table 4 below. B31.3 section 304.7.2 (a) allows the use of unlisted components with extensive operating experience.

Table 4. B31.3 Unlisted Components

Component	Manufacturer	Classification	Pressure rating psi	System design pressure psid	Comments
2-3/4 inch conflat HV feed thru	CeramTec	Unlisted	1500	100	See note 1
Purity monitor fiber optic feed thru	FNAL	Unlisted	>100	100	See note 2
2-3/4 inch conflat	Kurt J Lesker	Unlisted	>100	100	See note 3
4-1/2 inch conflat	Kurt J Lesker	Unlisted	>115	115	See note 4
10 inch conflat modified	FNAL	Unlisted	>100	100	See note 5
Braided metal flexible hose - 1/2 inch	Hosemaster	Unlisted	1186	115	See note 6
Braided metal flexible hose - 1 inch	Hosemaster	Unlisted	718	115	See note 6
Braided metal flexible hose - 2 inch	Hosemaster	Unlisted	449	115	See note 6
Braided metal flexible hose - 3 inch	Hosemaster	Unlisted	346	115	See note 6
VCR fittings	Swagelok	Unlisted	1900	115	See note 7
Tube weld fittings	Swagelok	Unlisted	2400	115	See note 8
6 inch tube cap	GVC Direct	Unlisted	150	115	See note 9
Liquid argon pump	Barber-Nichols	Unlisted	115	115	See note 10
Vacuum insulated flexible hoses	Technifab Products	Unlisted	150	100	See note 11
Electric vaporizer	Cryogenic Experts	Unlisted	500	100	See note 12
Conflat vacuum valve	Varian	Unlisted	100	100	See note 13

Notes

1 This is the only manufacturer internal pressure rating given to a conflat that the author is aware of.

2 The FNAL fabricated component consists of a modified 2-3/4" conflat. It was pressure tested to 375 psi to qualify it for use at 100 psi per ASME B16.9 2007. The tensile strength of 304 SS is 75 ksi and the B31.3 allowable is 20 ksi. This ratio results in the 3.75x test pressure. Pressure test available in the Appendix E.

3 The CeramTec manufacturer pressure rating of 1,500 psi (note 1) and the successfully pressure test of an identical conflat with material removed (note 2) qualify this size conflat for use at 100 psi.

4 A 4-1/2 conflat pair was pressured tested to 2600 psi before leakage occurred. This qualifies the flange for use at 693 psi according to the ASME B16.9 proof test procedure. The pressure test documentation is available in the appendix. There is also extensive service experience operating this size conflat at pressures up to 415 psid at both room and liquid argon temperatures.

5 The modified 10 inch conflat was analyzed per 304.7.2(d) and the results are available in section 2.4.2.

6 Hosemaster supplies a pressure rating for these hoses and extensive service experience exists for both liquid nitrogen and liquid argon.

7 The lowest pressure rating of any Swagelok VCR fitting is 1900 psi. Extensive service experience exists for Swagelok VCR fittings in liquid argon service at pressures up to 415 psid.

8 The lowest pressure rating of any Swagelok tube weld fitting is 2400 psi. Extensive service experience exists for Swagelok tube weld fittings in liquid argon service at pressures up to 415 psid.

9 The vendor states that this tube cap is sold for use on ASME stamped vessels with MAWPs up to 150 psig.

10 The vendor rates this vacuum jacketed pump for use at 115 psid.

11 These are rated by the mfg. and are used only for special procedures.

12 The electric vaporizer vaporizes liquid argon and heats the vapor to 70 °F. The vaporizer shuts its outlet solenoid valve if the outlet drops below -25 °F. The vaporizer has its own hard wired controls and is not part of the PLC system.

13 The Varian vacuum valve was pressure tested to 375 psi to qualify it for use at 100 psi per ASME B16.9 2007. The tensile strength of 304 SS is 75 ksi and the B31.3 allowable is 20 ksi. This ratio results in the 3.75x test pressure. Pressure test available in the Appendix E.

2.4.2 – Inline Purity Monitor 10 inch Conflat Flange

The top flange of the inline purity monitor vessel consists of a modified 10 inch conflat flange populated with three 2 ¾ ” conflat flanges and three ½ ” VCR fittings. The details of the holes in the flange are shown in drawing MD-486009 and the details of the purity monitor vessel itself are shown in MD-466995 (both drawings are in Appendix B). A simple ANSYS FEA model of the modified conflat flange was made to check the stress under internal pressure. B31.3 304.7.2(d) allows for detailed stress analysis of a component with results evaluated as described in the BPV Code Section VIII Division 2 Part 5. The model consists of a round plate with holes in it that represent the smaller conflats and VCR penetrations. Evenly distributed around the perimeter of each hole is a force that represents the force due to pressure on the conflats and VCRs. For the 2-3/4" conflats the pressure area diameter is taken to be 1.76" which is the diameter of the largest portion of the hole in the 10 inch conflat such that the force is

$$F = A \times P = \frac{\pi}{4}\left(1.76^2\right)in^2 \times 100\frac{lb_f}{in^2} = 243\ lb_f.$$

For the ½" VCR fitting the pressure area diameter is taken to be 0.51" which is the diameter of the corresponding thru hole in the 10 inch conflat and the force is calculated to be

$$F = A \times P = \frac{\pi}{4}\left(0.51^2\right)in^2 \times 100\frac{lb_f}{in^2} = 20.4\ lb_f.$$

The 100 psi pressure is applied across the conflat out to the knife edge seal diameter of 8.6 inches. Symmetry is utilized to analyze half of the plate. The model reports a maximum von Mises stress of 5,926 psi. This is far below the lowest allowable stress of 16,700 psi for stainless steel in B31.3. Runs with various mesh densities confirmed convergence on this maximum stress. The details of the model are shown in the following two figures.

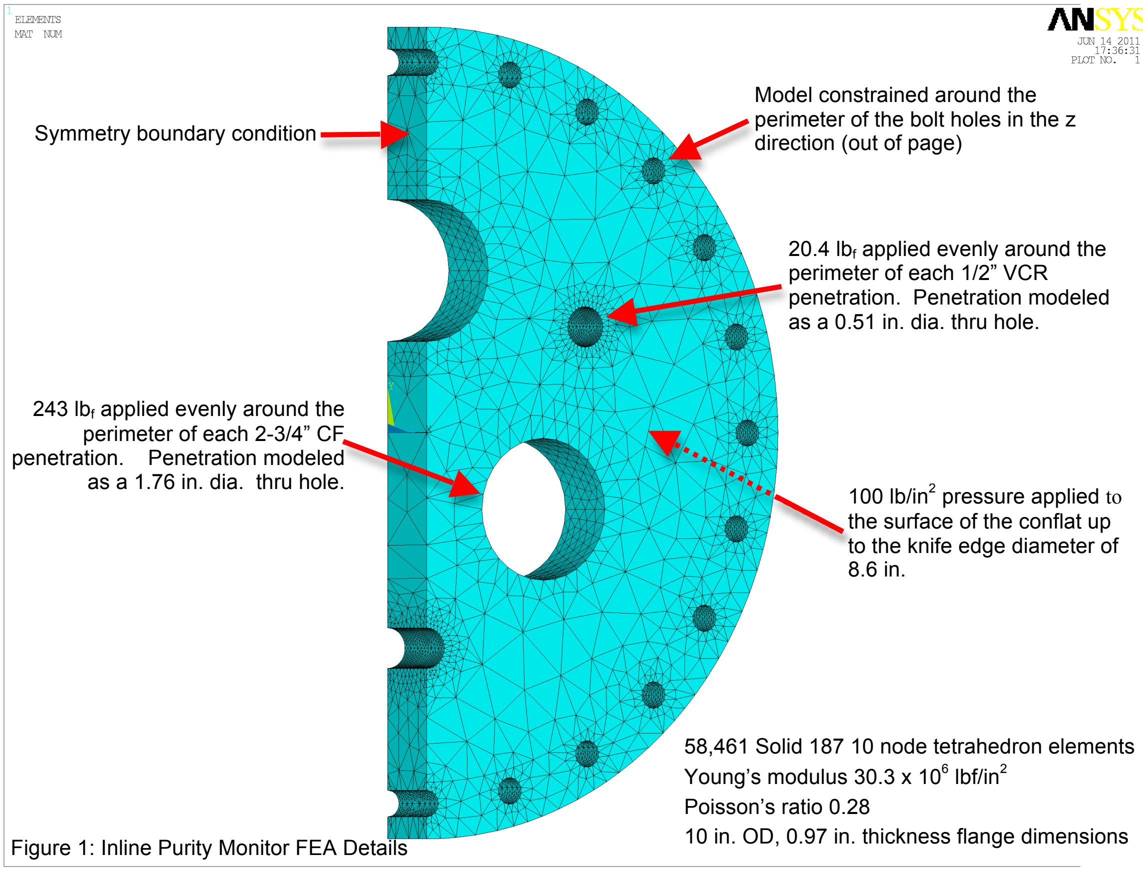


Figure 1: Inline Purity Monitor FEA Details

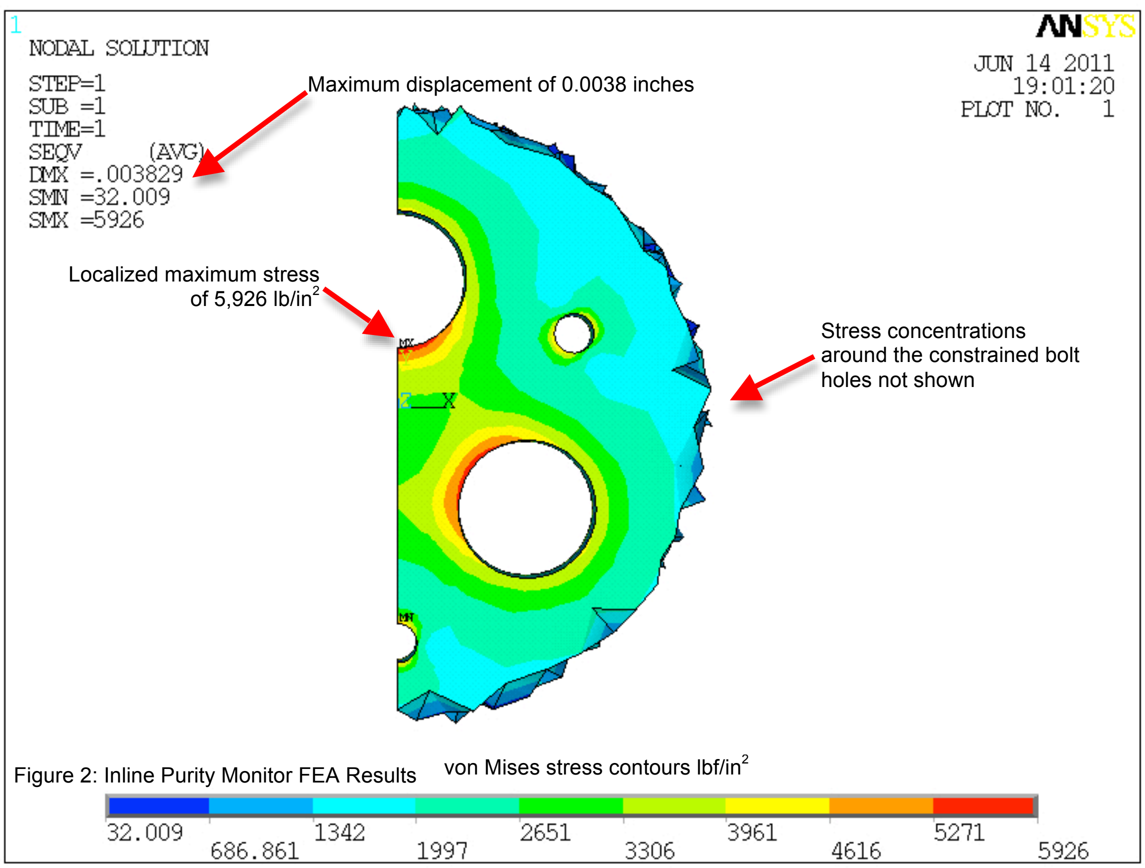


Figure 2: Inline Purity Monitor FEA Results

Twenty-four bolts hold the modified conflat flange to the mating vessel conflat flange. These 5/16-24 bolts are stainless steel with a minimum strength of 70,000 psi. The conflat knife edge that provides the seal between the flanges has a diameter of 8.6 inches. The force *F* applied to the top flange at MAWP is then

$$F = A \times P = \frac{\pi}{4}\left(8.6^2\right) in^2 \times 100 \frac{lb_f}{in^2} = 5{,}809\ lb_f .$$

Each bolt has a tensile stress area A_t of 0.0581 in^2. The stress in each bolt is then

$$\sigma_{bolt} = \frac{F}{A_t} = \frac{\dfrac{5{,}809\ lb_f}{24}}{0.0581\ in^2} = 4{,}166 \frac{lb_f}{in^2} .$$

The bolt stress due to the maximum pressure difference the flange will see is only 6 percent of the minimum bolt strength. The conflat bolts are torqued to 15 ft-lb$_f$. Thus the bolt preload corresponds to a tensile stress calculated in the following manner.

$$\sigma_{bolt} = \frac{\dfrac{T_i}{0.21 \times d}}{A_t} = \frac{\dfrac{15\, ft \times lb_f \times \dfrac{12\ in}{ft}}{0.21 \times 0.3125\ in}}{0.0581\ in^2} = 47{,}209 \frac{lb_f}{in^2}$$

Even if all the additional force due to internal pressure is transferred to the bolts in addition to the bolt preload, the bolts are still well below their rated strength.

2.5 – Relieving System

2.5.1 Trapped Volume Reliefs

The main venting scenario for the vacuum insulated liquid argon piping is the loss of insulating vacuum. There are no system sources of pressure that can supply gas at a pressure greater than the 100 psig mawp of the liquid argon piping.

It is assumed air fills the vacuum space because air has a higher thermal conductivity than argon. Fire is not considered due to the lack of combustible material in the vicinity of the piping and the fact that the long length of the piping makes it unlikely a significant portion could be involved in a fire.

Heat input into a 100 foot long section of vacuum jacketed is computed for both the 1” SCH 10 / 3” SCH 10 and 2” SCH 10 / 5” SCH 10 combinations. No section of vacuum jacketed piping that can become a trapped volume protected by a single relief valve is near 100 feet in length.

Figure 3 shows the geometry for the vacuum insulated piping trapped volume relief calculation. The vacuum jacket is set to 590.67 ^{o}R (131 ^{o}F) and the inner line is fixed at 205.7 ^{o}R which is the saturation pressure that corresponds to the flow rating pressure of 126.2 psia. The inner pipe is wrapped with 20 layers of mli. Both radiation and convection provide heat input to the outer layer of the mli. Thru the mli conduction and radiation are considered between each of the 20 layers, and between the final layer and the inner cryogen containing pipe.

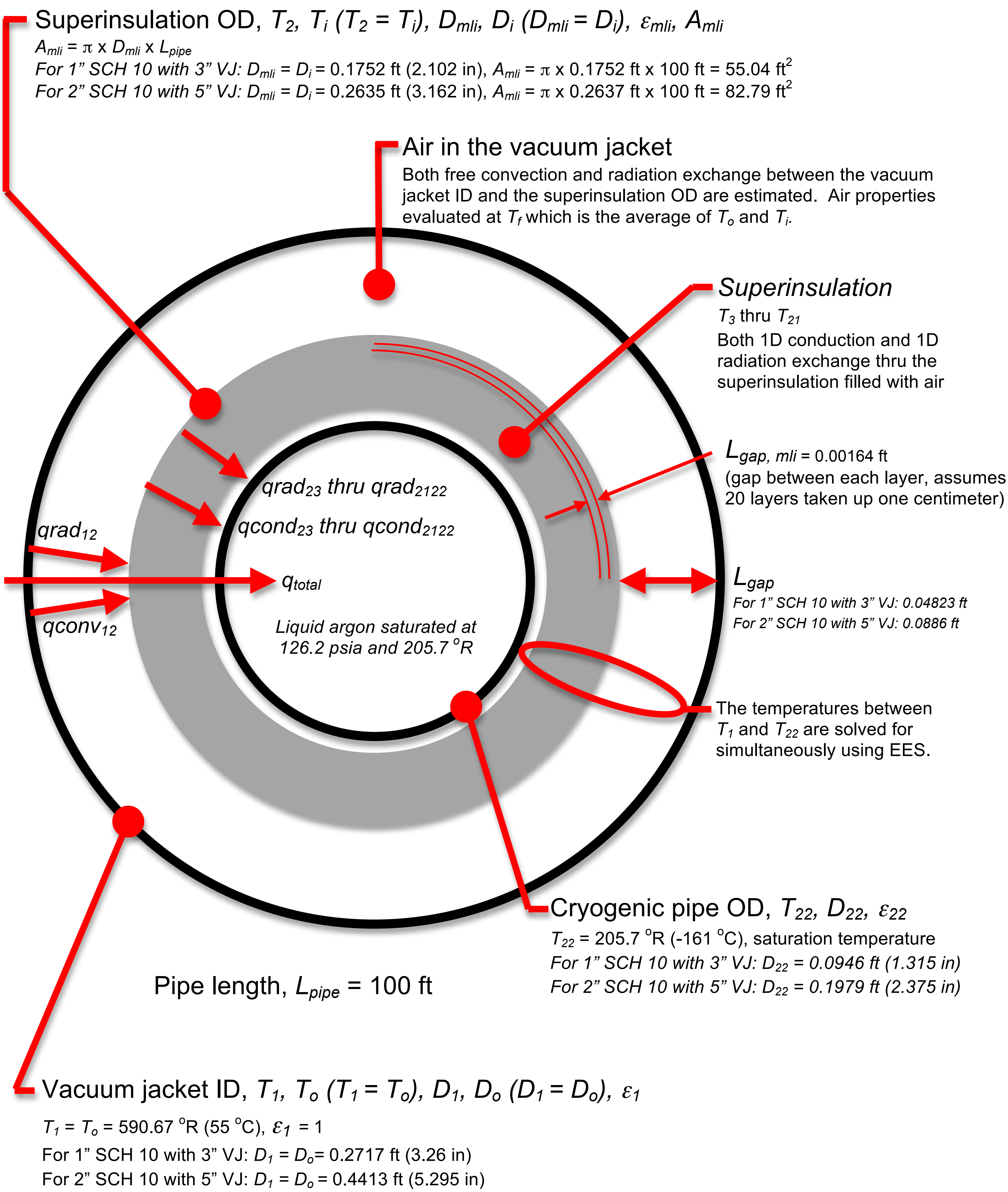


Figure 3: Vacuum jacketed piping trapped volume relief calculation parameters

Radiation between the vacuum jacket ID and the mli OD, *$qrad_{12}$*, is estimated using equation 13.25 from the 4th edition of Incropera and Dewitt's Fundamentals of Heat and Mass Transfer. The emissivity of the vacuum jacket, ε_1, is 1 while the emissivity of each layer of super insulation, ε_{mli}, is estimated as 0.05. The following is an example calculation for the 2" SCH 10 / 5" SCH 10 combination:

$$qrad_{12} = \frac{A_{mli}\sigma\left(T_1^4 - T_2^4\right)}{\frac{1}{\varepsilon_{mli}} + \frac{1-\varepsilon_1}{\varepsilon_1} \times \frac{D_{mli}}{D_1}} = \frac{82.79\,ft^2 \times \frac{1.714 \times 10^{-9}\ Btu}{hr \times ft^2 \times R^4} \times \left(590.67^4 - 387.649^4\right) R^4}{\frac{1}{0.05} + \frac{1-1}{1} \times \frac{0.2635\,ft}{0.4413\,ft}} = 358.5\ \frac{Btu}{hr}.$$

Convection between the mli OD and the vacuum jacket ID, *$qconv_{12}$*, is modeled as free convection between concentric cylinders using equations 9.58, 9.59, and 9.60 from Incropera and Dewitt.

$$qconv_{12} = \frac{2\pi k_{eff}}{\ln\left(\frac{D_o}{D_i}\right)}\left(T_o - T_i\right)L_{pipe}, \quad \frac{k_{eff}}{k_{air}} = 0.386\left(\frac{Pr_{air}}{0.861 + Pr_{air}}\right)^{1/4}\left(Ra_c^*\right)^{1/4}$$

$$Ra_c^* = \frac{\left[\ln\left(\frac{D_o}{D_i}\right)\right]^4}{L_{gap}^3\left(D_i^{-3/5} + D_o^{-3/5}\right)^5} Ra_L, \quad Ra_L \ \frac{g\beta\left(T_o - T_i\right)L_{gap}^3}{\nu_{air}\alpha_{air}}$$

$$\beta = \frac{1}{T_f}, \quad \alpha_{air} = \frac{k_{air}}{\rho_{air}c_{P_{air}}}, \quad Pr_{air} = \frac{\nu_{air}}{\alpha_{air}}, \quad T_f = \frac{T_i + T_o}{2}$$

Ra_L = Rayleigh number, dimensionless, the ratio of buoyancy forces and (the product of) thermal and momentum diffusivities.

k_{eff} = effective thermal conductivity, Btu / (hr x ft x ^oR), the thermal conductivity that a stationary fluid would have to transfer the same amount of heat as the moving fluid.

L_{gap} = distance between the heated and cooled surfaces, 0.0889 ft, for the gap between the mli OD and the VJ ID for the 2" SCH 10 / 5" SCH 10 combination.

k_{air} = thermal conductivity of the air in the vacuum space, Btu / (hr x ft x ^oR), evaluated for air at ambient pressure and the average temperature of the two enclosure surfaces *T_f* (average of *T_o* and *T_i*) by EES.

Pr_{air} = Prandtl number, dimensionless (ratio of the momentum and thermal diffusivities), evaluated at the average temperature of the two enclosure surfaces T_f (average of T_o and T_i).

g = gravitational acceleration, 4.173×10^8 ft/hr^2.

β = volumetric thermal expansion coefficient, 1 / ^oR, computed as 1 / T_f.

α_{air} = thermal diffusivity, ft^2/hr, evaluated for air at ambient pressure and T_f by EES.

ν_{air} = kinematic viscosity, ft^2/hr, evaluated for air at ambient pressure and T_f by EES.

ρ_{air} = density, lb/ft^3, evaluated for air at ambient pressure and T_f by EES.

c_{Pair} = specific heat at constant pressure, Btu / (lb x ^oR), evaluated for air at ambient pressure and T_f by EES.

The above equations were solved simultaneously using EES which also evaluated the fluid properties. An example calculation for the 2" SCH 10 / 5" SCH 10 combination is shown below.

$$qconv_{12} = \frac{2\pi k_{eff}}{\ln\left(\frac{D_o}{D_i}\right)}\left(T_o - T_i\right)L_{pipe} = \frac{2\pi \times 0.1314 \frac{Btu}{hr \times ft \times^o R}}{\ln\left(\frac{0.4413\,ft}{0.2635\,ft}\right)}\left(590.67 - 516.6\right)^o R \times 100\,ft = 11{,}869\,\frac{Btu}{hr}$$

$$\frac{k_{eff}}{k_{air}} = 0.386\left(\frac{Pr_{air}}{0.861 + Pr_{air}}\right)^{1/4}\left(Ra_c^*\right)^{1/4} = 0.386\left(\frac{0.6648}{0.861 + 0.6648}\right)^{1/4}\left(524{,}327\right)^{1/4} = 8.439$$

$$Ra_c^* = \frac{\left[\ln\left(\frac{D_o}{D_i}\right)\right]^4}{L_{gap}^3\left(D_i^{-3/5} + D_o^{-3/5}\right)^5}Ra_L = \frac{\left[\ln\left(\frac{0.4413\,ft}{0.2635\,ft}\right)\right]^4}{0.0886^3\,ft^3\left(0.2635^{-3/5} + 0.4413^{-3/5}\right)^5}72{,}269 = 524{,}327$$

$$Ra_L = \frac{g\beta\left(T_o - T_i\right)L_{gap}^3}{\nu_{air}\alpha_{air}} =$$

$$4.173 \times 10^8\,\frac{ft}{hr^2} \times \frac{0.001806}{^oR} \times \left(590.67 - 516.6\right)^o R \times 0.0889^3\,ft^3 \times \frac{hr}{0.6004\,ft^2} \times \frac{hr}{0.9032\,ft^2} = 72{,}269$$

$$\beta = \frac{1}{T_f} = \frac{1}{553.6^o R} = 0.001806, \quad \alpha_{air} = \frac{k_{air}}{\rho_{air}c_{P_{air}}} = 0.01557\,\frac{Btu}{hr \times ft \times^o R} \times \frac{ft^3}{0.07167\,lb} \times \frac{lb \times^o R}{0.2405\,Btu} = 0.9032\,\frac{ft^2}{hr}$$

$$Pr_{air} = \frac{\nu_{air}}{\alpha_{air}} = \frac{0.6004\,\frac{ft^2}{hr}}{0.9032\,\frac{ft^2}{hr}} = 0.6648, \quad T_f = \frac{T_i + T_o}{2} = \frac{516.6 + 590.67}{2}\,^o R = 553.6^o R$$

Radiation between the mli layers themselves is modeled as exchange between parallel planes (Incropera and Dewitt equation 13.24) in the following manner where subscript two indicates the outer mli layer and subscript three the adjacent mli layer.

$$qrad_{23} = \frac{A_{mli}\sigma\left(T_2^4 - T_3^4\right)}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} = \frac{82.79\,ft^2 \times \frac{1.714 \times 10^{-9}\,Btu}{hr \times ft^2 \times R^4} \times \left(516.563^4 - 501^4\right)R^4}{\frac{1}{0.05} + \frac{1}{0.05} - 1} = 29.77\,\frac{Btu}{hr}$$

Conduction in the air between the mli layers is modeled as 1-D conduction. The thermal conductivity, k_{air}, is evaluated at the average temperature of the vacuum jacket and the outer mli layer which is conservative because the thermal conductivity decreases as the temperature decreases radially thru the mli layers. The outer mli layer surface area is used for all mli layers which is conservative because the surface area decreases for each mli layer. An example mli conduction calculation for the 2” SCH 10 / 5” SCH 10 combination is shown below.

$$qcond_{23} = \frac{k_{air} A_{mli}(T_2 - T_3)}{L_{gap\ mli}} = \frac{0.01557 \frac{Btu}{hr \times ft \times {}^oR} \times 82.79\, ft^2 \times (516.563 - 501)^oR}{0.00164\, ft} = 12{,}198 \frac{Btu}{hr}$$

In CGA section 6.2.2 the following equation is used to calculate the minimum required flow capacity for insulated containers for liquefied compressed gases for conditions other than fire:

$$Q_a = \frac{(590 - T)}{4(1660 - T)} F G_i U A$$

where:

U = Overall heat transfer coefficient to the liquid, $\frac{Btu}{hr \cdot ft^2 \cdot {}^oF}$.

T = Temperature specified in 6.1.3, 205.7 ^{o}R for saturated argon vapor at 126.2 psia.

F = Correction factor for pressure drop and temperature rise in line to relief valve, specified in 6.1.4., 1.0 because the trapped volume reliefs are attached with piping whose length is less than 2 feet.

A = Average surface area of the inner and outer surfaces areas of the container insulation. The outer surface area of the superinsulation, A_{mli}, is used for these calculations.

G_i = Gas factor for insulated containers.

Q_a = Flow capacity required at applicable flow rating pressure and 60 ^{o}F in cubic feet per minute of free air.

For the CGA calculation this heat flow must be converted to an overall heat transfer coefficient to the liquid.

$$U = \frac{q_{total}}{A \Delta T} = \frac{12{,}227 Btu}{hr} \times \frac{1}{82.79 ft^2} \times \frac{1}{(590.7 - 205.7)} = 0.3836 \frac{Btu}{hr \times ft^2 \times {}^\circ F}$$

To calculate the initial estimate of the relief capacity needed, a gas factor, G_i, must be computed. From page 25 of the CGA S-1.3—2008, when the flow rating pressure is less than 40% of the critical pressure ($\frac{126.2 psia}{705.4 psia} \cdot 100 = 17.9\%$), the following is used to compute G_i.

$$G_i = \frac{73.4(1660 - T)}{CL}\sqrt{\frac{ZT}{M}}$$

where

L = Latent heat of product at flow rating pressure, $60.68\frac{Btu}{lb_m}$ for saturated conditions at 126.2 psia .

.

C = Constant for vapor related to ratio of specific heats (k=c_p/c_v) at standard conditions. k = 1.67 for Argon at 60 ^{o}F and 14.696 psia (from EES) which corresponds to C = 378 (Table 4 of CGA S-1.3—2008).

Z = Compressibility factor for saturated vapor at 126.2 psia

$$Z = \frac{Pv}{RT,} \qquad Z = \frac{126.2\frac{lbf}{in^2} \times 0.3685\frac{ft^3}{lb}144\frac{in^2}{ft^2}}{\frac{1545\frac{ft \times lbf}{lbmol \times {}^oR}}{39.948\frac{lb}{lbmol}} \times 205.7^oR} = 0.842.$$

T = Flow rating temperature, 205.7 ^{o}R.

M = Molecular weight of gas, 39.948 for argon.

v = specific volume, saturated vapor at flow rating pressure of 126.2 psia, $0.3685\frac{ft^3}{lb_m}$.

G_i is calculated to be $\frac{73.4(1660 - 205.7)}{378 \times 60.68}\sqrt{\frac{0.842 \times 205.7}{39.948}} = 9.69.$

The volumetric flow rate was found to be

$$Q_a = \frac{(590 - 205.7)}{4(1660 - 205.7)}1.0 \times 9.69 \times 0.3836 \times 82.79 = 20.38\frac{ft^3}{\min}\text{of air.}$$

A similar calculation for a 100 foot length of 1” SCH 10 liquid argon pipe surrounded by 3” SCH 10 vacuum jacket yields a required flow of 13.73 SCFM.

The liquid argon purification piping is protected by numerous Circle Seal 5100 series relief valves. The smallest of these relief valves, the 2MP size, has a flow of 25 SCFM of air at 10% over its 100 psig cracking pressure. The trapped volume that includes the inline purity monitor vessel between valves AV-557-Ar and MV-593-Ar is protected by PSV-587-Ar which has a flow capacity of 282 SCFM of air at 10% over its 100 psig cracking pressure. The surface area of the purity monitor vessel is estimated below and is far less then the surface area calculated for aforementioned trapped volumes such that it is adequately relieved.

$$\pi \times 6\ in \times 49.12\ in + \frac{\pi}{4} \times 6^2 in^2 \times 2 = 982\ in^2 = 6.82\ ft^2$$

The relief valves are listed in the instrument list which is available in Appendix A.

The trapped volume relief valve (PSV-497-Ar) sizing for the un-insulated pump cool down line is documented on the next 9 pages. This relief protects a “long” un-insulated ½” OD stainless tube.

Trapped Vol. RV sizing - pump prime vent

rev. 11-02-12

This calculation is for sizing the relief rate for the trapped volume in the LAPD pump priming vent, located on the pump suction.

API 521 standard is used for evaluating the overpressure scenarios and establishing a basis for the relief design. API 520 is used for sizing.

CGA S-1.3 is not applicable because a vent pipe is not a storage container. For reference, API 520/521 standards are more thorough than the CGA.

This is indoor piping and are no flammable materials stored near the pipe so fire exposure is not a credible concern.

This pipe is not insulated, but will form an ice layer during use which would remain until the line warms up. This ice would be there should the line be blocked in with LAr. A thin layer is used in the calculations.

Constants and Defined values used in subsequent calculations

Acceleration: $g_{accel} = 9.8 \cdot \frac{m}{s^2}$

Gravitational Constant: $g_c := g_{accel} \cdot \frac{lbm}{lbf}$ $\quad g_c = 32.2 \cdot \frac{ft \cdot lbm}{lbf \cdot s^2}$ $\quad g_c = 1.0 \cdot \frac{\frac{kg \cdot m}{s^2}}{N}$

Gas Constant: $R_g := 8.314472 \cdot \frac{joule}{mole \cdot K}$

Atmospheric pressure: $atm = 14.70 \cdot psi$ $\quad atm = 14.70 \cdot \frac{lbf}{in^2}$

Pipe Data

Pipe outside diameter

$Pipe_{ID} := \frac{1}{2} \cdot in$

$Tube_{wall} := 0.049 \cdot in$

Pipe Length (liquid containing pipe up to max liquid level, split into horizontal and vertical)

$Pipe_{LV} := (110 + 48) \cdot in - 2 \cdot ft$ Pipe lengths from piping FEA

$Pipe_{LH} := (6 + 13 + 25 + 103 + 35 + 108 + 15) \cdot in$

$Pipe_{LV} = 11.2 \cdot ft$ $\quad Pipe_{LH} = 25.4 \cdot ft$

$Pipe_{OD} := Pipe_{ID} + 2 \cdot Tube_{wall}$

$Pipe_{L.tot} := Pipe_{LV} + Pipe_{LH}$ $\quad Pipe_{L.tot} = 36.6 \cdot ft$

$Pipe_{OD} = 0.598 \cdot in$

metal thermal conductivity (316 SS)

$k_M := 8.11 \cdot \frac{W}{m \cdot K}$

Scenario Check List (API 521)

1. Closed outlets
Closing the block valves can be a source of overpressure.

2. Coolant failure - Not applicable.
3. Top reflux failure - Not applicable.
4. Side reflux failure - Not applicable
5. Lean Oil failure to absorber - Not applicable.

6. Accumulation of noncondensables
Not applicable. System designed for cyrogenic operation.

7. Entrance of highly volatile material - Not applicable. System designed for cyrogenic operation.

8. Overfilling
Overfilling is not a source of over pressure. This pipe can be filled by the pump, but the pump maximum discharge pressure is below 100 psig.

9.Control Failure
A control failure with the supply (LAPD tank) produces pressures that are well within the pipe design pressure.

10. Abnormal heat or vapor input
There are no heaters in proximity to this vent pipe. Abnormal heat input is not credible.

11. Split exchanger tube - Not applicable.

12. Internal explosion - Not applicable, no flammables being used.
13. Chemical reaction - Not applicable, only cryogens in vessel.
14. Hydraulic expansion - Not applicable.

15. Exterior fire
The vent pipe is not near flammables. The closest equipment (LAPD tank) is not flammable. Exterior fire is not credible.

16. Power failure (steam, electric, air, other) - same as item 8.

Item **1** above is identified as possible sources of overpressure. (Trapped volume)

Data and Params for estimating air convection heat transfer coefficient

Argon Temp. @ relief P **Approximate Film T**

$T_{room} := (25 + 273.15)\cdot K$ $T_{Ar.sat} := 114.06\cdot K$ $\dfrac{T_{room} + T_{Ar.sat}}{2} = 206.1\,K$

Air Property Data @ Film T

density $\rho_{air} := 1.7164\cdot\dfrac{kg}{m^3}$

thermal cond. $k_{air} := 19.013\cdot\dfrac{mW}{m\cdot K}$

Prandtl # $Pr_{air} := 0.7240$

Coef. Thermal Expansion (Vol. Expansivity) $\beta_{air} := 0.00489\cdot\dfrac{1}{K}$

Kinematic Visc $\nu_{air} := 0.07968\cdot\dfrac{cm^2}{s}$

Thermal Diff. $\alpha_{air} := 0.11\cdot\dfrac{cm^2}{s}$

$\Delta T := T_{room} - T_{Ar.sat}$ $\Delta T = 184.1\,K$

Rayleigh #, based on L

$$Ra_L := \frac{g_{accel}\cdot\beta_{air}\cdot\Delta T\cdot Pipe_{LV}{}^3}{\nu_{air}\cdot\alpha_{air}}$$

$Ra_L = 4\times10^{12}$

Grashoff #

$$Gr_L := \frac{Ra_L}{Pr_{air}}$$

$Gr_L = 5.5\times10^{12}$ Grashoff number exceeds 10^9 so the flow is turbulent

Estimate of Vertical Air Natural Convection Heat Transfer Coefficient

Assumption: There is constant boiling inside the pipe, therefore there is constant heat flux.

$$Nu_L := \left[0.825 + \frac{0.387 \cdot Ra_L^{\frac{1}{6}}}{\left[1 + \left(\frac{0.492}{Pr_{air}}\right)^{\frac{9}{16}}\right]^{\frac{8}{27}}} \right]^2$$

Churchill-Chu correlation for isothermal vertical wall, laminar or turbulent flow, any Ra and Pr
ref: Fundamentals of Heat and Mass Transfer, by Incropera, DeWitt, Bergman and Lavine, 7th ed.

$$Nu_L = 1.7 \times 10^3$$

heat transfer coeff., natural convection

$$h_{conv.vert} := \frac{Nu_L \cdot k_{air}}{Pipe_{LV}} \qquad h_{conv.vert} = 9.7 \cdot \frac{W}{m^2 \cdot K}$$

Doubling the estimated convective heat transfer coefficient from above to make sure the value used is higher than actual.

Estimate of Horizontal Air Natural Convection Heat Transfer Coefficient

Rayleigh #, based on dia.

$$Ra_D := \frac{g_{accel} \cdot \beta_{air} \cdot \Delta T \cdot Pipe_{OD}^{\;3}}{\nu_{air} \cdot \alpha_{air}}$$

$$Ra_D = 3.5 \times 10^5$$

Assumption: There is constant boiling inside the pipe, therefore there is constant heat flux.

$$Nu_D := \left[0.60 + \frac{0.387 \cdot Ra_D^{\frac{1}{6}}}{\left[1 + \left(\frac{0.559}{Pr_{air}} \right)^{\frac{9}{16}} \right]^{\frac{8}{27}}} \right]^2$$

ref: Fundamentals of Heat and Mass Transfer, by Incropera, DeWitt, Bergman and Lavine, 7th ed.

$$Nu_D = 10.9$$

heat transfer coeff., natural convection

$$h_{conv.horiz} := \frac{Nu_D \cdot k_{air}}{Pipe_{OD}} \qquad h_{conv.horiz} = 13.7 \cdot \frac{W}{m^2 \cdot K}$$

Heat Transfer Coef. , average

$$h_{air.conv} := \left(\frac{Pipe_{LV}}{Pipe_{LV} + Pipe_{LH}} \cdot h_{conv.vert} + \frac{Pipe_{LH}}{Pipe_{LV} + Pipe_{LH}} \cdot h_{conv.horiz} \right)$$

$$h_{air.conv} = 12.5 \cdot \frac{W}{m^2 \cdot K}$$

Heat Transfer Coefficient for uninsulated pipe full of trapped LAr

argon liq thermal cond. @ 110 psig, sat.

$$k_{Ar.liq} := 90.942 \cdot \frac{mW}{m \cdot K}$$

Boiling argon heat transfer coef.

$$h_{Ar\_boil} := 2000 \cdot \frac{kW}{m^2 \cdot K}$$

Just using a high value, instead of looking for one.

GAr & LAr density

$$\rho_{GAr} := 42.687 \cdot \frac{kg}{m^3}$$

$$\rho_{LAr} := 1211.6 \cdot \frac{kg}{m^3}$$

@ relieving conditions

Heat of Vaporization

$$Hv := 135 \cdot \frac{kJ}{kg}$$

@ relieving conditions

$$\rho_{Ar.CGA.STD} := 1.6875 \cdot \frac{kg}{m^3}$$

@ 60F per CGA

Ice Thermal Conductivity

$$k_{ice} := 1.88 \cdot \frac{W}{m \cdot K}$$

per Cryogenic Heat Transfer, By Barrons

Only a thin ice layer is assumed, which has only a small impact on the overall heat transfer.

Total Pipe Areas for overall U calculation

$$Area_{OD} := 2\pi \frac{Pipe_{OD}}{2} \cdot Pipe_{L.tot} \qquad Area_{ID} := 2\pi \frac{Pipe_{ID}}{2} \cdot Pipe_{L.tot}$$

$$Area_{OD} = 5.7 \cdot ft^2 \qquad Area_{ID} = 4.8 \cdot ft^2$$

Relationship between overall U and individual heat path elements

$$UA := \frac{1}{\dfrac{1}{h_{air.conv} \cdot Area_{OD}} + \dfrac{0.1 \cdot mm}{k_{ice} \cdot Area_{OD}} + \dfrac{Tube_{wall}}{k_M \cdot \left(\dfrac{Area_{OD} + Area_{ID}}{2}\right)} + \dfrac{1}{h_{Ar\_boil} \cdot Area_{ID}}}$$

$$U := \frac{UA}{Area_{OD}} \qquad U = 12.4 \cdot \frac{W}{m^2 \cdot K}$$

Convection Heat Load

$$Q_{air.conv} := U \cdot Area_{OD} \cdot (300K - T_{Ar.sat}) \qquad Q_{air.conv} = 1.230 \cdot kW$$

Radiant Heat Load Estimate

For completeness, estimate of radiant energy that could be absorbed by the uninsulated pipe, using simple black body assumptions.

$F_{2.1} := 1$

Configuration factor, a value of 1 implies that all radiant energy from object 2 (surroundings) is intercepted by object 1 (pipe).

$\sigma := \left(5.6404 \cdot 10^{-8}\right) \cdot \frac{W}{m^2 \cdot K^4}$

Stefan-Boltzmann constant for black body total radiated energy

$Q_{radiant} := Area_{OD} \cdot F_{2.1} \cdot \sigma \cdot \left[(300 \cdot K)^4 - (89.1 \cdot K)^4 \right]$

Radiant Heat Load

$Q_{radiant} = 241.2 \cdot W$

$Req_{relief.GAr} := \frac{Q_{air.conv} + Q_{radiant}}{Hv}$ $\qquad$ $Req_{relief.GAr} = 39.2 \cdot \frac{kg}{hr}$

This is the relief rate for the largest credible relief scenario; blocked in, LAr full.

Relief valve capacity @ 110% of setpoint

Relief valve Set Pressure vessel Design P (MAWP)

$P_{set} := 100 \cdot psi$ gauge

Relieving pressure: overpressure of 10%

$P_R := P_{set} \cdot 1.10 + atm$ abs

$P_R = 124.7 \cdot psi$

Physical Properties of vapor @ 10% Pres. Accumulation (REFPROP)

Molecular Weight

$M_w := 39.95 \cdot \frac{kg}{kgmole}$

Saturation temperature at relieving pressure

$T_{in} := T_{Ar.sat}$ $T_{in} = 114.1\,K$

Gas Compressibility

$Z := 0.84837$

Gas Heat Capacity Ratio @ relieving Temperature

$\gamma := 2.0453$

Actual Relief Rate - Based on a selected relief valve orifice size

For the Generant selected, relieve valve, the actual orifice size is checked with the certified Kd value (ASME) for that relief valve.

Selected Orifice Size $As := \pi \cdot \left(\frac{0.400 \cdot in}{2}\right)^2$ $As = 0.126 \cdot in^2$

Coeff. of Discharge $Kd := 0.34$

>> Specific to CRV8V with setpoint between 90-130 psig <<

Back Pressure Factor $Kb := 1.0$

Combination Factor $K_c := 1.0$

$$Wm_A := Kd \cdot Kb \cdot K_c \cdot P_R \cdot As \cdot \sqrt{\frac{\gamma \cdot g_c \cdot M_w}{T_{in} \cdot R_g \cdot Z} \cdot \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma+1}{\gamma-1}}}$$

API 520.P1 eq. 5 sect. 5.6.3.1.1, with expanded "C" factor and unit consistency and conversion handled by Mathcad. The gas constant and gravitational constant are explicitly shown.

$Wm_A = 1027 \cdot \frac{lb}{hr}$ $Wm_A = 466 \cdot \frac{kg}{hr}$

$Req_{relief.GAr} = 39.2 \cdot \frac{kg}{hr}$

The selected relief valve exceeds the required relief capacity and is therefore adequate for protecting the priming vent pipe.

1: air: Specified state points [Barometric pressure: 14.696 psia]

	Temperature (K)	Pressure (psig)	Density (kg/m^3)	Cp/Cv	Comp. Factor	Quality (kg/kg)
1	206.10	0.0000000000000079476	1.7164	1.4055	0.99786	Superheated

	Molar Mass	Therm. Cond. (mW/m-K)	Viscosity (uPa-s)	Kin. Viscosity (cm^2/s)	Therm. Diff. (cm^2/s)	Prandtl
1	28.965	19.013	13.676	0.079679	0.11006	0.72399

	Vol. Expansivity (1/K)
1	0.0048906

Air properties at film T

1: argon: Specified state points [Barometric pressure: 14.696 psia]

	Temperature (K)	Pressure (psig)	Density (kg/m^3)	Cp/Cv	Comp. Factor	Quality (kg/kg)	Heat of Vapor. (kJ/kg)	Molar Mass
1	114.06	110.00	42.687	2.0453	0.84837	1.0000	134.99	39.948
2	114.06	110.00	1211.6	2.6897	0.029890	0.00000	134.99	39.948

	Therm. Cond. (mW/m-K)	Viscosity (cPoise)	Kin. Viscosity (cm^2/s)	Therm. Diff. (cm^2/s)	Prandtl	Vol. Expansivity (1/K)
1	8.2471	0.0098179	0.0023000	0.0025336	0.90780	0.014357
2	90.942	0.12720	0.0010498	0.00059760	1.7568	0.0067853

Argon properties at the relieving pressuring.

where the Rayleigh number,

$$Ra_L = Gr_L\, Pr = \frac{g\beta(T_s - T_\infty)L^3}{\nu\alpha} \tag{9.25}$$

is based on the characteristic length L of the geometry. Typically, $n = \frac{1}{4}$ and $\frac{1}{3}$ for laminar and turbulent flows, respectively. For turbulent flow it then follows that $\overline{h}_L$ is independent of L. Note that all properties are evaluated at the film temperature, $T_f \equiv (T_s + T_\infty)/2$.

9.6.1 The Vertical Plate

Expressions of the form given by Equation 9.24 have been developed for the vertical plate [5–7]. For laminar flow ($10^4 \lesssim Ra_L \lesssim 10^9$), $C = 0.59$ and $n = 1/4$, and for turbulent flow ($10^9 \lesssim Ra_L \lesssim 10^{13}$), $C = 0.10$ and $n = 1/3$. A correlation that may be applied over the *entire* range of Ra_L has been recommended by Churchill and Chu [8] and is of the form

$$\overline{Nu}_L = \left\{0.825 + \frac{0.387\, Ra_L^{1/6}}{[1 + (0.492/Pr)^{9/16}]^{8/27}}\right\}^2 \tag{9.26}$$

Although Equation 9.26 is suitable for most engineering calculations, slightly better accuracy may be obtained for laminar flow by using [8]

$$\overline{Nu}_L = 0.68 + \frac{0.670\, Ra_L^{1/4}}{[1 + (0.492/Pr)^{9/16}]^{4/9}} \qquad Ra_L \lesssim 10^9 \tag{9.27}$$

When the Rayleigh number is moderately large, the second term on the right-hand side of Equations 9.26 and 9.27 dominates, and the correlations are the same form as Equation 9.24, except that the constant, C, is replaced by a function of Pr. Equation 9.27 is then in excellent quantitative agreement with the analytical solution given by Equations 9.21 and 9.20. In contrast, when the Rayleigh number is small, the first term on the right-hand side of Equations 9.26 and 9.27 dominates, and the equations yield the same behavior since $0.825^2 \approx 0.68$. The presence of leading constants in Equations 9.26 and 9.27 accounts for the fact that, for small Rayleigh number, the boundary layer assumptions become invalid and conduction parallel to the plate is important.

It is important to recognize that the foregoing results have been obtained for an isothermal plate (constant T_s). If the surface condition is, instead, one of uniform heat flux (constant q''_s), the temperature difference $(T_s - T_\infty)$ will vary with x, increasing from the leading edge. An approximate procedure for determining this variation may be based on results [8, 9] showing that $\overline{Nu}_L$ correlations obtained for the isothermal plate may still be used to an excellent approximation, if $\overline{Nu}_L$ and Ra_L are defined in terms of the temperature difference at the midpoint of the plate, $\Delta T_{L/2} = T_s(L/2) - T_\infty$. Hence, with $\overline{h} \equiv q''_s/\Delta T_{L/2}$, a correlation such as Equation 9.27 could be used to determine $\Delta T_{L/2}$ (for example, using a trial-and-error technique), and hence the midpoint surface temperature $T_s(L/2)$. If it is assumed that $Nu_x \propto Ra_x^{1/4}$ over the entire plate, it follows that

$$\frac{q''_s x}{k\Delta T} \propto \Delta T^{1/4} x^{3/4}$$

or

$$\Delta T \propto x^{1/5}$$

Hence the temperature difference at any x is

$$\Delta T_x \approx \frac{x^{1/5}}{(L/2)^{1/5}} \Delta T_{L/2} = 1.15 \left(\frac{x}{L}\right)^{1/5} \Delta T_{L/2} \tag{9.28}$$

A more detailed discussion of constant heat flux results is provided by Churchill [10].

The foregoing results may also be applied to *vertical* cylinders of height L, if the boundary layer thickness δ is much less than the cylinder diameter D. This condition is known to be satisfied [11] when

$$\frac{D}{L} \gtrsim \frac{35}{Gr_L^{1/4}}$$

Cebeci [12] and Minkowycz and Sparrow [13] present results for slender, vertical cylinders not meeting this condition, where transverse curvature influences boundary layer development and enhances the rate of heat transfer.

Example 9.2

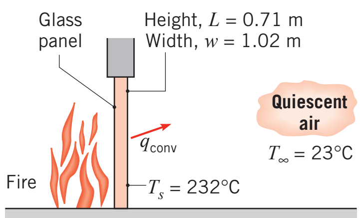
A glass-door firescreen, used to reduce exfiltration of room air through a chimney, has a height of 0.71 m and a width of 1.02 m and reaches a temperature of 232°C. If the room temperature is 23°C, estimate the convection heat rate from the fireplace to the room.

Solution

Known: Glass screen situated in fireplace opening.

Find: Heat transfer by convection between screen and room air.

Schematic:



Assumptions:

1. Screen is at a uniform temperature T_s.
2. Room air is quiescent.
3. Ideal gas.
4. Constant properties.

Properties: Table A.4, air ($T_f = 400$ K): $k = 33.8 \times 10^{-3}$ W/m·K, $\nu = 26.4 \times 10^{-6}$ m^2/s, $\alpha = 38.3 \times 10^{-6}$ m^2/s, $Pr = 0.690$, $\beta = (1/T_f) = 0.0025$ K^{-1}.

which yields

$$q' = (17.5 + 22.8 + 15.5)\ \text{W/m} = 55.8\ \text{W/m}$$

The insulation therefore provides a 76% reduction in heat loss to the ambient air by natural convection.

2. Although they have been neglected, radiation losses may still be significant. From Equation 1.7 with ε assumed to be unity and $T_{sur} = 288\ \text{K}$, $q'_{rad} = 398\ \text{W/m}$ for the uninsulated duct. Inclusion of radiation effects in the energy balance for the insulated duct would reduce the outer surface temperatures, thereby reducing the convection heat rates. With radiation, however, the total heat rate $(q'_{conv} + q'_{rad})$ would increase.

9.6.3 The Long Horizontal Cylinder

This important geometry has been studied extensively, and many existing correlations have been reviewed by Morgan [22]. For an isothermal cylinder, Morgan suggests an expression of the form

$$\overline{Nu}_D = \frac{\bar{h}D}{k} = C\,Ra_D^n \tag{9.33}$$

where C and n are given in Table 9.1 and Ra_D and $\overline{Nu}_D$ are based on the cylinder diameter. In contrast, Churchill and Chu [23] have recommended a single correlation for a wide Rayleigh number range:

$$\overline{Nu}_D = \left\{0.60 + \frac{0.387\,Ra_D^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{8/27}}\right\}^2 \qquad Ra_D \lesssim 10^{12} \tag{9.34}$$

The foregoing correlations provide the average Nusselt number over the entire circumference of an isothermal cylinder. As shown in Figure 9.8 for a heated cylinder, local Nusselt numbers are influenced by boundary layer development, which begins at $\theta = 0$ and concludes at $\theta < \pi$ with formation of a plume ascending from the cylinder. If the flow remains laminar over the entire surface, the distribution of the local Nusselt number with θ is characterized by a maximum at $\theta = 0$ and a monotonic decay with increasing θ. This decay would be disrupted at Rayleigh numbers sufficiently large ($Ra_D \gtrsim 10^9$) to permit transition to turbulence within the boundary layer. If the cylinder is cooled relative to the ambient fluid, boundary layer development begins at $\theta = \pi$, the local Nusselt number is a maximum at this location, and the plume descends from the cylinder.

TABLE 9.1 Constants of Equation 9.33 for free convection on a horizontal circular cylinder [22]

Ra_D	C	n
10^{-10}–10^{-2}	0.675	0.058
10^{-2}–10^{2}	1.02	0.148
10^{2}–10^{4}	0.850	0.188
10^{4}–10^{7}	0.480	0.250
10^{7}–10^{12}	0.125	0.333

SEVENTH EDITION

Fundamentals of Heat and Mass Transfer

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$\text{FinalVelocity}(v_0,a,s) := \sqrt{v_0^2 + 2\cdot a\cdot s}$	Creates a user-defined function based on initial velocity (v_0), acceleration (a), and distance (s).
$\text{FinalVelocity}\left(80\frac{ft}{s}, 10\frac{ft}{sec^2}, 300ft\right) = 111.36\frac{ft}{s}$	Units must be attached to each argument.
$\text{FinalVelocity}(80,10,300) = 111.36$	In this example, the numbers used for the arguments are the same as above, but no units are attached to the numbers. The numeric result is the same as above, but no units are attached to the result. For engineering calculations you want units attached to all results. Therefore, make sure that units are attached to all the input information.
$\text{FinalVelocity}\left(54.545mph, 3.048\frac{m}{sec^2}, 100yd\right) = 111.35\frac{ft}{s}$	Input arguments can be mixed units.
$\text{FinalVelocity}(54.545,3.048,100) = 59.87$	If no units are attached to the arguments, and the units do not match, then the numeric result is incorrect. BE SURE TO ATTACH UNITS TO ALL THE INPUT ARGUMENTS.

Figure 4.22 Units in user-defined functions

Units in empirical formulas

Many engineering equations have empirical formulas. There are times when units may not work with the empirical equations. This can occur when the empirical formula raises a number to a power that is not an integer such as $x^{1/2}$ or $x^{2/3}$. If units are attached to "x" then the units of the result will not be accurate. In order to resolve this problem, divide the variable by the units expected of the equation, and then multiply the results by the same unit. For example, the shear strength of concrete (lbf/in^2-psi) is based on the square root of the concrete strength (psi). See Figures 4.23, 4.24, and 4.25 to see how to resolve the use of units in empirical formulas.

The Figures 4.23, 4.24, and 4.25 illustrate the following when dealing with units in empirical equations.

- Don't stop using units if they appear to not work with your equation.
- Divide the affected variables by the units in the system expected in the equation.
- It doesn't matter what input units you used as long as you divide by the units in the system expected to be used in the equation.
- After you divide by the units, then you may need to multiply again at some point in the equation by the same units.

Figure 4.26 illustrates another empirical equation using units.

$\phi := 0.85$ $\qquad f'_c := 4000\text{psi}$

Input variables: phi and strength of concrete.

$\text{ShearStrength}_1 := 2\cdot\phi\cdot\sqrt{f'_c}$

Empirical Formula for shear strength of concrete based on f'_c.

Result should be in psi.

$\text{ShearStrength}_1 = 7318.35\ \dfrac{\text{lb}^{0.5}}{\text{ft}^{0.5}\cdot\text{s}}$

Incorrect result because of the units under the square root.

The result needs to be in psi. The empirical formula takes the square root of f'_c (in psi) and expects the result in psi, but this did not happen in the above equation.

In order to resolve this problem, divide f'_c by psi to make it unitless, and then multiply the result by psi.

$\text{ShearStrength}_2 := 2\cdot\phi\cdot\sqrt{\dfrac{f'_c}{\text{psi}}}\cdot\text{psi}$ $\qquad \text{ShearStrength}_2 := 107.52\ \text{psi}$ Correct result.

Figure 4.23 Units in empirical formulas

If an empirical formula expects a number to be in a particular unit (in this case psi), then it is important to divide the number by psi, even if the variable was input in a different unit system. For example, if you are using a US formula, and if f'_c were input in MPa, you would still need to divide by psi, not MPa. The result can be converted to MPa. See below for an example.

$f'_c := 27.579\text{MPa}$ Change the input to MPa. (This step isn't really necessary. Mathcad already knew that f'_c was 27.579 MPa. It is done only to emphasize that f'_c was input as SI.)

$f'_c = 4000\ \text{psi}$ Even though f'_c was input in metric units, Mathcad knows that it is the same as 4000 psi and the result will be the same.

$\text{ShearStrength}_3 := 2\cdot\phi\cdot\sqrt{\dfrac{f'_c}{\text{psi}}}\ \text{psi}$ Since the equation is meant for US units, divide by psi, not MPa.

$\text{ShearStrength}_3 = 107.52\ \text{psi}$ The result is the same, even though f'_c was input in metric units.

$\text{ShearStrength}_3 = 0.74\ \text{MPa}$ The result can be displayed as MPa.

$\text{ShearStrength}_4 := 2\cdot\phi\cdot\sqrt{\dfrac{f'_c}{\text{MPa}}}\cdot\text{MPa}$ Result is incorrect if you try to divide by MPa. (Because the formula was written for US units.)

$\text{ShearStrength}_4 = 1294.85\ \text{psi}$

$\text{ShearStrength}_4 = 8.93\ \text{MPa}$ Incorrect result

Figure 4.24 Units in empirical formulas

The same shear strength equation in SI form is: $0.166 \cdot \phi \cdot \sqrt{f'_c}$ where f'_c is in MPa.

$f'_c = 4000$ psi $\quad f'_c = 27.58$ MPa

These values were input in the previous example.

$$SI\_ShearStrength := 0.166 \cdot \phi \cdot \sqrt{\frac{f'_c}{MPa}} \cdot MPa$$

This equation was written for SI units; therefore, divide by MPa.

$SI\_ShearStrength = 107.47$ psi

$SI\_ShearStrength = 0.74$ MPa

The results are the same as using the US equation.

When using empirical formulas it is critical to know what units the equation was written for. It is then critical to divide by the units the equation was written for, not what the input units are.
The following illustrates why this is important. Notice how f'_c divided by psi = 4000 and f'_c divided by MPa = 27.58. These are the numeric numbers expected in the US and SI shear equations respectively.

$$\frac{f'_c}{psi} = 4000 \qquad \frac{f'_c}{MPa} = 27.58$$

Figure 4.25 Same example as in Figure 4.24, but in SI form

The Hazen-Williams equation for calculating the fluid velocity in a pipe system is Velocity=1.318*C_H*$R^{0.63}$*$S^{0.54}$. Where C_H is a coefficient related to the pipe material, L is length of pipe in feet, R is the hydraulic radius (which for a pipe flowing full is the Area in feet divided by the circumference in feet), and S is the slope of the energy line or the hydraulic gradient h_f/L.

Calculate the velocity given the following:

Hydraulic gradient: 90 feet over 1000 feet

$C_H := 110 \quad D := 24in \quad h_f := 90 \cdot ft \quad Length := 1000ft$

$$Velocity := 1.32 \cdot C_H \cdot \left(\frac{\frac{\pi \cdot D^2}{4}}{\pi \cdot D}\right)^{0.63} \cdot \left(\frac{h_f}{Length}\right)^{0.54}$$

Result is not accurate because of the empirical formula and units.

$Velocity = 25.56\ ft^{0.63}$

$$Velocity := 1.32 \cdot C_H \cdot \left[\frac{\frac{\pi \cdot \left(\frac{D}{ft}\right)^2}{4}}{\pi \cdot \frac{D}{ft}}\right]^{0.63} \cdot \left(\frac{h_f}{Length}\right)^{0.54} \cdot \frac{ft}{sec}$$

$Velocity = 25.56\ \frac{ft}{s}$

$$1.32 \cdot 110 \cdot \left(\frac{2.0}{4}\right)^{0.63} \cdot \left(\frac{90}{1000}\right)^{0.54} = 25.56$$

With no units attached

Figure 4.26 Example of another empirical formula

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2.5.2 Vacuum Jacket Reliefs

According to the CGA S-1.3—2008 5.4, the area of a vacuum relief in sq. in. should be 0.00024 in^2/lb of vessel water capacity. The piping covered in this note has eight separate vacuum jacketed sections and each section has its own vacuum relief. The eight vacuum jacket sections are highlighted in Appendix A. Table 5 summarizes the volume of each section, the required relief area, and the available relief area. The volume of each section was estimated from the drawings available in Appendix B. The volume of the inner cryogenic line was not subtracted from the volume calculated using the outer pipe thus the volumes are conservative.

Table 5: Vacuum jacket reliefs

Vacuum jacket ID	Estimated volume ft^3	Water capacity lb	Required relief area in^2	Relief type	Relief area in^2
1	3.5	218	0.052	1" CVI w/out spring	1.23[1]
2	9.3	580	0.139	1" CVI w/out spring	1.23[1]
3	3.7	231	0.055	three 1" CVIs	0.15[2]
4	18.8	1173	0.282	parallel plate	8.35[3]
5	1.2	75	0.018	1" CVI	0.05[4]
6	18.8	1173	0.282	parallel plate	8.35[3]
7	5.7	356	0.085	parallel plate	5.41[5]
8	1.7	106	0.025	1" CVI	0.05[4]

Notes

1. A 1" CVI vacuum seal-off valve with the spring removed operates as a parallel plate relief and has a flow area of 1.23 in^2.
2. Russ Rucinski measured the flow area of a 1" CVI vacuum seal-off valve as 0.05 in^2 at lift. This document is available in the appendix. Thus three such valves have a combined area of 0.15 in^2.
3. Each filter vessel vacuum jacket has a parallel plate relief without a spring that has a flow area of 8.35 in^3.
4. Russ Rucinski measured the flow area of a 1" CVI vacuum seal-off valve as 0.05 in^2 at lift. This document is available in the appendix.
5. The inline purity monitor vacuum jacket has a Fermilab parallel plate relief fabricated from drawing # 106391. Tom Peterson notes that the flow area is 5.41 inches in an email available in the appendix for this relief.

2.6 – Weld Documentation (In-process inspection, Radiography, etc.)

According to Chapter 5031 of the Fermilab ES&H Manual, all pressure piping systems at Fermilab fall under the scope of the ASME/ANSI B31 code series unless specifically excluded. The code series stipulates that pressure piping systems be inspected and tested according to the specific requirements of the code. For ASME/ANSI B31.3 Process Piping, which is the relevant code series for this piping system, the required testing is outlined in Chapter VI, Section 341. These requirements pertain to piping systems in Normal Fluid service which applies to piping systems at pressures above 150 psi or piping systems below 150 psi with design temperatures lower than -20 ºF, which is the case here. Normally radiographic examination of at least 5% of the welds is required but in certain cases the use of radiographic examination is difficult or all together impossible. This is the case here where assembly techniques prevent access to specific welds for radiography. The B31.3 piping code allows the use of in-process examination in lieu of radiography on a weld-for-weld basis for these cases. In-process inspection forms were created in consultation with the Fermilab weld shop which documents items such as joint preparation and cleanliness, welding machine type, joint fit-up and alignment, filler material, purge gas (purity, flow, oxygen concentration), inspection of root pass and inspection of final pass. Appendix C includes both the in-process weld inspection guidelines and a sample in-process weld inspection form. The original forms for all welds are maintained in the project document database.

http://lartpc-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=639

In-process weld documentation associated with the amendment has been added to the location linked above.

2.7 – System Pressure Test

ES&H Section 5034 and the B31.3 Code require that all new pressure piping systems be subject to a pressure test to assure that they can be operated safely. The pressure test shall be performed at 110% of MAWP for pneumatic tests. The test pressure for each section is noted on the flow schematic in Appendix A and the test documentation is tabulated in Appendix E.

Pressure tests required for the modifications will be added to Appendix E.

Appendix A
Flow Schematics and Valve and Instrument List.

The flow schematic and valve and instrument list have been updated to reflect LAPD run 2 modifications.

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
MV	101	Ar	SHT-1	7-	C	connection to HP Ar dewar #1	manual valve	NA	3000 psig	Matheson	53-48T
MV	102	Ar	SHT-1	7-	D	connection to HP Ar dewar #2	manual valve	NA	3000 psig	Matheson	53-48T
MV	103	Ar	SHT-1	7-	D	connection to HP Ar dewar #3	manual valve	NA	3000 psig	Matheson	53-48T
PI	104	Har	SHT-1	6-	E	regeneration gas trailer pressure	local pressure indicator	NA	3000 psig	Wika	NA
PT	105	Ar	SHT-1	6-	B	HP Ar header pressure	pressure transmitter	0 - 3000 psig	3750 psig	Setra	C280E
PRV	106	HAr	SHT-1	7-	F	Ar/H2 from trailer	pressure regulator	50	3000 psig	Matheson	3201
PSV	108	HAr	SHT-1	7-	F	Ar/H2 from trailer relief	relief valve	100 psig	400 psig	Rockwood Swendeman	710NBEF-A
PRV	110	Ar	SHT-1	7-	E	header from HP Ar dewars	pressure regulator	85 psig	3000 psig	Victor	VTS 450 E 580
PT	111	Ar	SHT-1	6-	E	Ar/H2 trailer pressure	pressure transmitter	0 - 3000 psia	3000 psia	Setra	225130CPAC411B1
MV	113	Ar	SHT-1	7-	D	HP Ar header	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
PSV	114	Ar	SHT-1	7-	E	header from HP Ar dewars	relief valve	100 psig	2400 psig	Circle-Seal	5100-4MP
MV	115	Ar	SHT-1	7-	E	HP Ar header blowdown	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
MV	116	Ar	SHT-1	7-	E	HP Ar supply to LAPD tank	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
MV	118	Ar	SHT-1	4-	D	Argon Source #2 vent valve	manual valve	NA	1500 psig	Swagelok	B-44XS6
MV	119	Ar	SHT-1	6-	D	Argon Source #2 hookup #1	manual valve	NA	3000 psig	Matheson	53-48T
MV	120	Ar	SHT-1	6-	D	Argon Source #2 hookup #2	manual valve	NA	3000 psig	Matheson	53-48T
MV	121	Ar	SHT-1	6-	D	Argon Source #2 hookup #3	manual valve	NA	3000 psig	Matheson	53-48T
MV	122	Ar	SHT-1	6-	D	Argon Source #2 hookup #4	manual valve	NA	3000 psig	Matheson	53-48T
PT	123	Ar	SHT-1	6-	D	Ar bottle header header	pressure transmitter	0 - 3000 psia	3000 psia	Setra	225130CPAC411B1
PRV	124	Ar	SHT-1	5-	D	Ar bottle header header	pressure regulator	75	3000 psig	Victor	VTS 450 E 580
PSV	125	Ar	SHT-1	4-	D	Ar bottle header header	relief valve	100 psig	2400 psig	Circle-Seal	5100-4MP
MV	126	Ar	SHT-1	4-	D	Argon source #2	manual valve	NA	1500 psig	Swagelok	B-44XS6
MV	128	Ar	SHT-1	6-	E	Argon Source #3 hookup #1	manual valve	NA	3000 psig	Matheson	53-48T
MV	129	Ar	SHT-1	6-	E	Argon Source #3 hookup #2	manual valve	NA	3000 psig	Matheson	53-48T
MV	130	Ar	SHT-1	6-	E	Argon Source #3 hookup #3	manual valve	NA	3000 psig	Matheson	53-48T
MV	131	Ar	SHT-1	6-	E	Argon Source #3 hookup #4	manual valve	NA	3000 psig	Matheson	53-48T
PT	132	Ar	SHT-1	6-	E	Argon Source #3 manifold pressure	pressure transmitter	0 - 3000 psia	3000 psia	Setra	225130CPAC411B1
PRV	133	Ar	SHT-1	5-	E	Argon source #3 header	pressure regulator	65	3000 psig	Victor	VTS 450 E 580
PSV	134	Ar	SHT-1	4-	E	Argon source #3 header	relief valve	100 psig	2400 psig	Circle-Seal	5100-4MP
MV	135	Ar	SHT-1	4-	E	Argon Source #3 vent valve	manual valve	NA	1500 psig	Swagelok	B-44XS6
MV	137	Ar	SHT-1	4-	E	Argon Source #3	manual valve	NA	1500 psig	Swagelok	B-44XS6
PT	138	N2	SHT-1	7-	G	N2 trailer	pressure transmitter	0-100 psig	>150 psig	Setra	C206, 100 psig, top mounted bayonet
LT	139	N2	SHT-1	7-	G	N2 trailer	press diff (level) transmitter	0-100 "wc	3000 psig	Cameron (formally Barton)	9A-IND224-GC-LA IT
SP	140	N2	SHT-1	5-	G	liq. N2 from N2 trailer to phase sep. outdoor section	Y-strainer (particulate filter)	NA	400 psig	McMASTER-CARR	44125K45 - 200 mesh
TE	141	N2	SHT-1	5-	G	liq. N2 from N2 trailer to phase sep. outdoor section	temperature element	70-400K	>200 psig	OMEGA	Platinum RTD PR-18-2-100-1/4-9-E
MV	142	N2	SHT-1	5-	G	liq. N2 from N2 trailer to vaporizer	manual shutoff valve	NA	600 psig	CPC-Cryolab	ES4-088-TPG standard length bonnet, 1", NPT, globe body
PSV	143	N2	SHT-1	4-	G	liq. N2 from N2 trailer to vaporizer	relief valve trapped volume	100 psig	2400 psig	Circle-Seal	5180B-4M-100
SV	144	N2	SHT-1	3-	G	GN2 supply to Pc4	solenoid valve	NA	300 psig	Magnatrol	16L44Z, 24 VDC
PI	145	N2	SHT-1	4-	G	N2 gas from vaporizer to regen gas header / outdoor section	local pressure indicator	0-160 psig	>200 psig	US Gauge	US Gauge Series P1535 - 2.5" Dial Gauge 110795
TE	146	N2	SHT-1	4-	G	N2 gas from vaporizer to regen gas header / outdoor section	temperature element	70-400K	>200 psig	OMEGA	Platinum RTD PR-18-2-100-1/4-9-E
MV	148	N2	SHT-1	5-	G	liq. N2 from N2 trailer to phase sep. blowdown / outdoor section	manual valve	NA	600 psig	CPC-Cryolab	ES4-088-TPG standard length bonnet, 1", NPT, globe body
PI	149	N2	SHT-1	4-	G	liq. N2 from N2 trailer to phase sep. outdoor section	local pressure indicator	0-160 psig	>200 psig	US Gauge	US Gauge Series P1535 - 2.5" Dial Gauge 110795
PSV	150	N2	SHT-1	4-	G	liq. N2 from N2 trailer to phase sep. outdoor section	relief valve trapped volume	100 psig	2400 psig	Circle-Seal	5180B-4M-100
CV	151	N2	SHT-1	3-	F	N2 gas from vaporizer to regen gas header / indoor section	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
MV	152	N2	SHT-1	3-	G	N2 gas from vaporizer to regen gas header / indoor section	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
CV	153	HAr	SHT-1	3-	F	Ar/H2 from trailer to LAPD filtration indoor section	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
MV	154	HAr	SHT-1	3-	F	Ar/H2 from trailer to LAPD filtration indoor section	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
MV	156	Ar	SHT-1	3-	C	HP Ar supply to LAPD tank	inside manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
FCV	157	Ar	SHT-1	3-	D	Ar purge header to purge #101	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	158	Ar	SHT-1	3-	D	Ar purge header to purge #102	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	159	Ar	SHT-1	3-	D	Ar purge header to purge #103	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	160	Ar	SHT-1	3-	D	Ar purge header to purge #104	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	161	Ar	SHT-1	3-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	162	Ar	SHT-1	2-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	163	Ar	SHT-1	2-	D	Ar purge header to purge #107	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	164	Ar	SHT-1	2-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	165	Ar	SHT-1	2-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	166	Ar	SHT-1	2-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
MV	167	Ar	SHT-1	3-	D	Ar bottle gas to Ar purge header	manual valve	NA	1000 psig	Swagelok	B-4HK
PSV	168	N2	SHT-1	3-	G	LN2 supply	relief valve trapped volume	100 psig	2400 psig	Circle-Seal	5100-4MP
MV	170	HAr	SHT-1	6-	F	Ar/H2 from trailer blowdown	manual valve	NA	1000 psig	Sharpe	84-6-6-P-G-SW
MV	171	HAr	SHT-1	7-	F	Ar/H2 from trailer	manual valve	NA	1000 psig	Sharpe	84-6-6-P-G-SW
PI	174	Ar	SHT-1	3-	D	Ar bottle gas to Ar purge header	pressure indicator	0 - 10 psig	10 psig	Matheson	0 - 10 psig gauge
PI	175	Ar	SHT-1	7-	E	header from HP Ar dewars	pressure indicator on regulator	0 - 3000 psig	3000 psig	Victor	Supplied with regulator
PI	176	Ar	SHT-1	7-	E	header from HP Ar dewars	pressure indicator on regulator	0 - 400 psig	400 psig	Victor	Supplied with regulator
PI	178	HAr	SHT-1	7-	F	Ar/H2 from trailer	pressure indicator on regulator	0 - 4000 psig	4000 psig	Wika	111.11.68.4000
PI	179	HAr	SHT-1	7-	F	Ar/H2 from trailer	pressure indicator on regulator	vac - 200 psig	200 psig	Matheson	Supplied with regulator
PI	180	Ar	SHT-1	5-	D	Ar bottle header header	pressure indicator on regulator	0 - 3000 psig	3000 psig	Victor	Supplied with regulator
PI	181	Ar	SHT-1	5-	D	Ar bottle header header	pressure indicator on regulator	0 - 400 psig	400 psig	Victor	Supplied with regulator
PI	182	Ar	SHT-1	5-	E	Ar bottle header header	pressure indicator on regulator	0 - 3000 psig	3000 psig	Victor	Supplied with regulator
PI	183	Ar	SHT-1	5-	E	Ar bottle header header	pressure indicator on regulator	0 - 400 psig	400 psig	Victor	Supplied with regulator
CV	186	Ar	SHT-1	3-	C	HP Ar supply to LAPD tank	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
CV	187	Ar	SHT-1	4-	C	Ar bottle gas to PC4	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
FCV	189	Ar	SHT-1	3-	D	Ar purge header to purge #111	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
FCV	190	Ar	SHT-1	3-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	191	Ar	SHT-1	3-	D	Ar purge header to purge #113	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	192	Ar	SHT-1	3-	D	Ar purge header to purge #114	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	193	Ar	SHT-1	3-	D	Ar purge header to purge #115	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	194	Ar	SHT-1	2-	D	Ar purge header to purge #116	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	195	Ar	SHT-1	2-	D	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	196	Ar	SHT-1	2-	D	Ar purge header to purge #118	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	197	Ar	SHT-1	2-	C	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	198	Ar	SHT-1	2-	C	Ar purge header to purge #120	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	199	Ar	SHT-1	2-	C	Ar purge header to purge #121	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	200	Ar	SHT-1	2-	C	Ar purge header spare	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	201	Ar	SHT-1	2-	C	Ar purge header to purge #123	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	202	Ar	SHT-1	2-	C	Ar purge header to purge #124	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
PI	206	Ar	SHT-1	3-	D	low pressure ar purge line pressure	local pressure indicator	0 - 100 psig	100 psig	US Gauge	162988
PRV	207	Ar	SHT-1	3-	D	low pressure ar purge line pressure regulator	pressure regulator	0.5 - 5 psi	250 psig	Matheson	3702
CV	208	Ar	SHT-1	4-	D	argon supply	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
PSV	209	N2	SHT-1	3-	G	trapped volume relief inside PC4	relief valve	100 psig	2400 psig	Circle -Seal	5100-4MP
PT	210	Air	SHT-1	6-	C	air bottle manifold	pressure transmitter	0-3000 psig	3000 psig	Ashcroft	K1
PT	211	Air	SHT-1	5-	C	air bottle manifold	pressure transmitter	0-3000 psig	3000 psig	Ashcroft	K1
MV	212	Air	SHT-1	5-	C	air bottle manifold	manual valve	NA	2500 psig	Swagelok	B-42XF2
MV	213	Air	SHT-1	5-	C	air bottle manifold	manual valve	NA	2500 psig	Swagelok	B-43YF2
PRV	214	Air	SHT-1	5-	C	air bottle manifold	pressure regulator	NA	> 2000 psig	Scott	Part of commercially purchased switchover manifold
PRV	215	Air	SHT-1	5-	C	air bottle manifold	pressure regulator	NA	> 2000 psig	Scott	Part of commercially purchased switchover manifold
PRV	216	Air	SHT-1	5-	C	air bottle manifold	pressure regulator	NA	> 2000 psig	Scott	Part of commercially purchased switchover manifold
PI	217	Air	SHT-1	5-	C	air bottle manifold	pressure indicator	0 - 400 psig	400 psig	Wika	NA
PSV	218	Air	SHT-1	5-	C	air bottle manifold	relief valve	100 psig	2400 psig	Circle-Seal	5100-4MP
MV	219	Ar	SHT-2	4-	D	Tank purge gas analyzers	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
MV	220	Ar	SHT-2	4-	D	Tank purge gas analyzers	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
FCV	221	Ar	SHT-2	4-	D	Tank purge gas analyzers	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
FCV	222	Ar	SHT-2	4-	D	Tank purge gas analyzers	rotameter	5-50 sccm	100 psig	Dwyer Instruments	RMA-151-SSV
AV	225	N2	SHT-1	6-	G	LN2 supply	automatic valve	NA	> 100 psig	Fermilab	Fermilab extended stem cryogenic control valve
MV	226	Ar	SHT-1	7-	B	connection to HP Ar dewar #3	manual valve	NA	3000 psig	Matheson	53-48T
MV	227	Ar	SHT-1	6-	E	H2/Ar pressure instrumentation	manual valve	NA	3500 psig	Swagelok	6LV-DLBW4
MV	228	Har	SHT-1	6-	B	Ar supply pressure instrumentation	manual valve	NA	3500 psig	Swagelok	6LV-DLBW4
PI	229	Ar	SHT-1	6-	B	argon dewar gas supply pressure instrumentation	pressure indicator	0 - 3000 psig	3000 psig	Wika	NA
MV	230	Har	SHT-1	4-	F	regeneration gas isolation	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
PI	231	N2	SHT-1	3-	G	nitrogen gas supply	pressure indicator	vac - 150 psig	150 psig	US Gauge	vac - 150 psig pressure gauge
MV	232	N2	SHT-1	3-	F	nitrogen gas supply	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
MV	233	V	SHT-1	2-	F	regeneration gas header	manual valve	NA	1000 psig	Swagelok	B-4HK
MV	234	V	SHT-1	2-	F	regeneration gas header	manual valve	NA	1000 psig	Swagelok	B-4HK
CV	236	Ar	SHT-1	3-	F	argon gas supply @ regen header	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
MV	237	Ar	SHT-1	3-	F	argon gas supply @ regen header	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
MV	238	Ar	SHT-1	4-	E	argon supply isolation	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
SP	239	N2	SHT-1	3-	F	nitrogen gas supply	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
SP	240	N2	SHT-1	3-	F	nitrogen gas supply	Y-strainer (particulate filter)	NA	200 psig	McMASTER-CARR	43935K556
SP	241	Har	SHT-1	3-	F	hydrogen argon gas supply	Y-strainer (particulate filter)	NA	200 psig	McMASTER-CARR	43935K556
SP	242	Ar	SHT-1	3-	F	argon gas supply @ regen header	Y-strainer (particulate filter)	NA	200 psig	McMASTER-CARR	43935K556
SP	243	N2	SHT-1	2-	F	nitrogen gas supply	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
PI	244	N2	SHT-1	2-	F	nitrogen gas supply	pressure indicator	vac - 150 psig	150 psig	US Gauge	FNAL Stock Item 1050-003500
MV	245	N2	SHT-1	2-	G	nitrogen gas supply	manual valve	NA	3000 psig	Swagelok	B-1VM4
SP	246	Ar	SHT-1	3-	E	argon supply	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
PI	247	Ar	SHT-1	3-	E	argon supply	pressure indicator	vac - 150 psig	150 psig	US Gauge	FNAL Stock Item 1050-003500
MV	248	Ar	SHT-1	3-	E	argon supply	manual valve	NA	3000 psig	Swagelok	B-1VM4
MV	249	Ar	SHT-1	3-	E	pneumatic valve actuation	manual valve	NA	2200 psig	Swagelok	B-43S6
PI	250	Ar	SHT-1	2-	E	pneumatic valve actuation	prssure indicator	vac - 150 psig	150 psig	US Gauge	FNAL Stock Item 1050-003500
MV	251	Ar	SHT-1	2-	E	pneumatic valve actuation	manual valve	NA	2200 psig	Swagelok	B-43S6
MV	252	Ar	SHT-1	2-	E	pneumatic valve actuation	manual valve	NA	2200 psig	Swagelok	B-43S6
MV	253	Ar	SHT-1	2-	E	pneumatic valve actuation	manual valve	NA	2200 psig	Swagelok	B-43S6
MV	254	Ar	SHT-1	2-	E	pneumatic valve actuation	manual valve	NA	2200 psig	Swagelok	B-43S6
MV	255	Ar	SHT-1	2-	E	pneumatic valve actuation	manual valve	NA	2200 psig	Swagelok	B-43S6
MV	256	Ar	SHT-2	4-	D	TPC signal purge	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
SP	258	Ar	SHT-1	3-	D	argon supply	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
SP	259	Ar	SHT-1	3-	C	argon supply	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
MV	260	Ar	SHT-1	3-	D	argon purges	manual valve	NA	250 psig	Matheson	100-S
MV	261	N2	SHT-1	7-	G	LN2 trailer instrumentation	manual valve	NA	1000 psig	Swagelok	B-4HK
PRV	262	N2	SHT-1	6-	G	LN2 trailer automatic shut off valve	pressure regulator	15 psig	300 psig	McMASTER-CARR	4289K21
PI	263	N2	SHT-1	6-	G	LN2 trailer automatic shut off valve	pressure indicator	0 - 30 psig	30 psig	McMASTER-CARR	gauge included with PRV-262-N2
PSV	264	N2	SHT-1	2-	G	trapped volume relief inside PC4	relief valve	100 psig	2400 psig	Circle -Seal	5100-4MP
PI	265	Ar	SHT-1	3-	C	argon utility gas	pressure indicator	vac - 150 psig	150 psig	US Gauge	FNAL Stock Item 1050-003500
PT	266	Ar	SHT-1	2-	E	argon utility gas	pressure transmitter	0 - 300 psig	300 psig	Setra	C206
PT	267	B	SHT-2	2-	C	barometric pressure	pressure transmitter	800 - 1100 mpa	1100 mpa	Setra	C278
SP	268	Har	SHT-1	3-	F	H2/Ar dilution	particulate filter	NA	200 psig	McMASTER-CARR	43935K556
CV	269	Har	SHT-1	3-	F	H2/Ar dilution	check valve	1 psig spring	1600 psig	Check-All Valve	BU-125-BR-BN-1.00-SS
MV	270	Har	SHT-1	3-	F	H2/Ar dilution	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
SP	271	N2	SHT-1	3-	G	nitrogen purge supply	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
MV	272	N2	SHT-1	3-	G	nitrogen purge supply	manual valve	NA	600 psig	Quadrant	M1FNSRRSLTT-100
CV	273	Ar	SHT-1	5-	E	Argon Source #3	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	274	Ar	SHT-1	5-	E	Argon Source #3	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	275	Ar	SHT-1	5-	E	Argon Source #3	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	276	Ar	SHT-1	5-	E	Argon Source #3	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	277	Ar	SHT-1	5-	C	Argon Source #2	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	278	Ar	SHT-1	5-	C	Argon Source #2	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	279	Ar	SHT-1	5-	C	Argon Source #2	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	280	Ar	SHT-1	5-	C	Argon Source #2	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	281	Ar	SHT-1	8-	E	Argon Source #1	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	282	Ar	SHT-1	8-	D	Argon Source #1	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	283	Ar	SHT-1	8-	C	Argon Source #1	check valve	NA	3000 psig	Matheson	580-CV-4-BP
CV	284	Ar	SHT-1	8-	C	Argon Source #1	check valve	NA	3000 psig	Matheson	580-CV-4-BP
MV	285	N2	SHT-1	2-	G	N2 liquid to LAPD	manual valve	NA	870 psig	Worcester	#C4466 PM SW
MV	286	AIR	SHT-1	3-	A	breathable air	manual valve	NA	250 psig	Worcester	1/4-416N
SP	287	AIR	SHT-1	3-	A	breathable air	particulate filter	NA	500 psig	McMASTER-CARR	4414K3
PI	288	AIR	SHT-1	3-	A	breathable air	pressure gauge	vac - 150 psig	150 psig	US Gauge	FNAL Stock Item 1050-003500
MV	289	AIR	SHT-1	3-	A	breathable air	manual valve	NA	250 psig	Worcester	1/4-416N
SP	290	AIR	SHT-1	3-	A	breathable air	particulate filter	NA	500 psig	McMASTER-CARR	4414K3
PI	291	AIR	SHT-1	3-	A	breathable air	pressure gauge	vac - 150 psig	150 psig	US Gauge	FNAL Stock Item 1050-003500
MV	292	AIR	SHT-1	3-	A	breathable air	manual valve	NA	250 psig	Worcester	1/4-416N
CV	293	AIR	SHT-1	6-	C	breathable air	check valve	10 psid	3000 psig	Nupro	B-4CP4
PI	294	AIR	SHT-1	6-	C	breathable air	pressure indicator	0 - 3000 psig	3000 psig	Wiki	NA
MV	295	AIR	SHT-1	5-	C	breathable air	manual valve	NA	2500 psig	Swagelok	B-42XF2
PI	296	AIR	SHT-1	5-	C	breathable air	pressure indicator	0 - 3000 psig	3000 psig	Wiki	NA
CV	297	AIR	SHT-1	5-	C	breathable air	check valve	10 psid	3000 psig	Nupro	B-4CP4
AE	298	Ar	SHT-2	4-	D	piston purge	oxygen sensor 1/3 elevation	0-25% O2	ambient	MSA	A-ULTIMAX-XP-E-14-U1S0-0010-100
AE	299	Ar	SHT-2	4-	D	piston purge	oxygen sensor 2/3 elevation	0-25% O2	ambient	MSA	A-ULTIMAX-XP-E-14-U1S0-0010-100
FCVE	300	Ar	SHT-2	7-	B	argon purge gas from HP Ar	gas mass flow control valve	0-6.5 SCFM	160 psia	Alicat Scientific Inc	MCR-250SLPM-D
SP	301	N2	SHT-2	7-	G	liq. N2 from N2 trailer to phase sep. indoor section	Y-strainer	NA	400 psig	McMASTER-CARR	44125K45 - 200 mesh
MV	302	N2	SHT-2	8-	G	liq. N2 from N2 trailer to phase sep. indoor section	manual shutoff valve	NA	600 psig	CPC-Cryolab	ES4-088-TPG standard length bonnet, 1", NPT, globe body
PI	303	N2	SHT-2	7-	G	liq. N2 from N2 trailer to phase sep. indoor section	local pressure indicator	0-160 psig	>200 psig	US Gauge	0-100 psig
PT	304	N2	SHT-2	7-	G	liq. N2 from N2 trailer to phase sep. indoor section	pressure transmitter	0-100 psig	>150 psig	Setra	C206, 100 psig, top mounted bayonet
FCV	305	N2	SHT-2	7-	G	liq. N2 from N2 trailer to phase sep. indoor section	solenoid valve	NA	300 psig	Magnatrol	16L44Z, 24 VDC
PSV	306	N2	SHT-2	7-	G	vacinity of phase sep	relief valve trapped volume	100 psig	2400 psig	Circle-Seal	5180B-4MP-100
PT	307	N2	SHT-2	6-	G	phase sep vent to vent header	pressure transmitter	0-100 psig	>150 psig	Setra	C206, 100 psig, top mounted bayonet
PI	309	N2	SHT-2	6-	G	phase sep vent to vent header	pressure indicator	0-100 psig	100 psig	US Gauge	162988
PRV	310	N2	SHT-2	7-	H	phase sep vent to vent header	back pressure regulator	20 psig	400 psig	Cash Valve	FR, 13782 (1/2"), 0-20 psig, cryogenic N2 gas
PSV	311	N2	SHT-2	7-	G	phase separator vessel	vessel overpressure relief valve	60 psig	2400 psig	Rockwood Swendeman	710-N-B-D-E-A-060 ASME Bronze RXSO, plain cap, B orifice, 3/4" inlet, 1" outlet, gas sect VIII, set at 60 psig
FCV	312	N2	SHT-2	6-	F	liq N2 from phase separator condenser	control valve	0 - 100 %	>300 psig	Fermilab	std Fermi LN2 valve w/badger actuator
MV	313	N2	SHT-2	6-	G	phase separator vessel	manual valve	NA	250 psig	see LT-316	NA
MV	314	N2	SHT-2	7-	G	phase separator vessel	manual valve	NA	250 psig	see LT-316	NA
MV	315	N2	SHT-2	6-	G	phase separator vessel	manual valve	NA	250 psig	see LT-316	NA
LT	316	N2	SHT-2	6-	G	phase separator vessel	level transmitter (pressure differential)	0-100%, 0-2psid	250 psig	Setra	2301-002PD-3V-11-A
PSV	317	N2	SHT-2	6-	F	liq N2 from phase separator condenser	relief valve trapped volume	100 psig	2400 psig	Circle-Seal	5180B-4MP-100
MV	318	Ar	SHT-2	4-	D	LAPD nozzle ar impurity purge vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
SV	319	N2	SHT-2	6-	G	liq N2 from phase separator condenser coil #3	solenoid valve	NA	300 psig	Magnatrol	16L44Z, 24 VDC
SV	320	N2	SHT-2	6-	F	liq N2 from phase separator condenser coil #2	solenoid valve	0 - 100 %	>300 psig	Fermilab	std Fermi LN2 valve w/badger actuator
SV	321	N2	SHT-2	6-	F	liq N2 from phase separator condenser coil #1	solenoid valve	NA	300 psig	Magnatrol	14L42, 24 VDC
MV	322	Ar	SHT-2	7-	C	LAPD tank level	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
LIT	323	Ar	SHT-2	7-	C	LAPD tank level	differential pressure indicator	0-10 psid (0-16.67 ft)	50 psid	Setra	231MS1
MV	324	Ar	SHT-2	7-	C	LAPD tank level	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	325	Ar	SHT-2	6-	C	LAPD tank level	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
LT	326	Ar	SHT-2	6-	C	LAPD tank liquid level	differential pressure transmitter	0-10 psid (0-16.67 ft)	500 psi	GP:50	316DPJLC
MV	327	Ar	SHT-2	6-	C	LAPD tank level	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	328	Ar	SHT-2	6-	C	LAPD tank level	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PSV	329	Ar	SHT-2	4-	F	Pump cool down trapped volume	relief valve	100 psig	2400 psig	Circle-Seal	5100-4MP
MV	330	Ar	SHT-2	5-	B	argon purge gas from HP Ar to LAPD tank	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
MV	331	Ar	SHT-2	3-	E	LAPD pressure control vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
PT	332	N2	SHT-2	5-	G	N2 vent from condenser	pressure transmitter	0-100 psig	>150 psig	Setra	C206, 100 psig, top mounted bayonet
MV	333	N2	SHT-2	5-	G	N2 vent from condenser	manual valve	NA	600 psig	CPC-Cryolab	ES4-088-TPG standard length bonnet, 1", NPT, globe body
PSV	334	Ar	SHT-2	4-	G	condenser	vessel overpressure relief valve	60 psig	2400 psig	Rockwood Swendeman	710-N-A-D-E-A-060 ASME Bronze RXSO, plain cap, A orifice, 3/4" inlet, 1" outlet, gas sect VIII, set at 60 psig
PSV	335	N2	SHT-2	5-	G	condenser	relief valve	60 psig	2400 psig	Circle-Seal	5180B-4M-100
CV	338	Ar	SHT-2	7-	B	argon purge gas from HP Ar	check valve	2 psi crack	3000 psig	Swagelok	6L-CW4VR8
MV	339	Ar	SHT-2	6-	B	argon purge gas from HP Ar	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
MV	340	Ar	SHT-2	6-	B	argon purge gas from HP Ar blowdown	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
MV	341	Ar	SHT-2	4-	E	LAPD nozzle ar impurity purge vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
FCV	342	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
MV	343	Ar	SHT-2	4-	E	LAPD nozzle ar impurity purge vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
FCV	344	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
FCV	345	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
MV	346	Ar	SHT-2	4-	D	LAPD nozzle ar impurity purge vent	manual valve	NA	375 psig	Carten	MD-250
MV	347	Ar	SHT-2	3-	E	LAPD nozzle ar impurity purge vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
FCV	348	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
FCV	349	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
MV	350	Ar	SHT-2	4-	E	tank vent	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8134
PCV	351	Ar	SHT-2	4-	E	LAPD pressure control vent	pressure control valve	NA	165 psid	Eden Cryogenics	BC-02146-8135
SV	351	Ar	SHT-2	4-	E	PCV-351-Ar	solenoid valve	NA	150 psig	ASCO	EF8327G041
MV	353	Ar	SHT-2	4-	E	LAPD pressure control vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
MV	354	Ar	SHT-2	4-	E	LAPD pressure control vent	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8119
FO	355-1	Ar	SHT-2	5-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.067"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-2	Ar	SHT-2	5-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.067"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-3	Ar	SHT-2	4-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.140"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-4	Ar	SHT-2	4-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.200"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-5	Ar	SHT-2	4-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.140"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-6	Ar	SHT-2	4-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.067"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-7	Ar	SHT-2	4-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.067"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-8	Ar	SHT-2	4-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.09"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-9	Ar	SHT-2	3-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.200"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-10	Ar	SHT-2	3-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.200"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-11	Ar	SHT-2	3-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.200"	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	355-12	Ar	SHT-2	3-	D	tank riser diffusion purge	orifice (drilled blind VCR seal)	0.200"	3500 psig	Swagelok	SS-8-VCR-2-BL
PI	358	Ar	SHT-2	3-	E	suction line to vent purge bellows pump	local pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ P/N 50328794
PT	359	Ar	SHT-2	3-	E	suction line to vent purge bellows pump	pressure transmitter	0-100 psia	150 psig	Setra	2251-100P-A-D4-11-B1
FCV	360	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
PSV	361	Ar	SHT-2	3-	E	vent purge bellows pump outlet	relief valve	40 psig	2400 psig	Circle-Seal	5100-2MP
PI	362	Ar	SHT-2	2-	E	vent purge bellows pump outlet	local pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ P/N 50328794
PT	363	Ar	SHT-2	2-	E	vent purge bellows pump outlet	pressure transmitter	0-100 psia	150 psig	Setra	2251-100P-A-D4-11-B1
MV	364	Ar	SHT-2	2-	E	vent purge bellows pump discharge to vent header	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
AE	365	V	SHT-2	3-	C	LAPD tank insulation	moisture analyzer and temperature sensor	0-100% RH -40 to +80 C	external to process	Vaisala	HMT100A12A621A2A1CB00
FCV	366	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
MV	367	Ar	SHT-2	2-	C	argon liquid return from filtration to tank	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8118
MV	368	Ar	SHT-2	3-	B	LAPD tank liquid to filtration pump	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8119
PT	369	Ar	SHT-2	4-	D	LAPD tank vapor pressure transmitter #1	pressure transmitter	0-5 psid	500 psi	GP:50	316DPJLC
PT	370	Ar	SHT-2	5-	D	LAPD tank vapor pressure transmitter #2	pressure transmitter	0-5 psid	500 psi	GP:50	316DPJLC
FCV	371	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
MV	372	Ar	SHT-2	5-	F	condenser liq overflow to LAPD tank	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8122
FCV	373	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
FCV	374	N2	SHT-2	7-	E	insulation purges	rotameter	0 - 20 SCFH	100 psig	Dwyer Instruments	RMA-6-SSV
MV	375	Ar	SHT-2	4-	D	LAPD nozzle ar impurity purge vent	manual valve	NA	375 psig	Carten	MD-250
FO	376	Ar	SHT-2	4-	E	tank riser diffusion purge	orifice	3/32" (~Cv=0.2)	3500 psig	Swagelok	SS-8-VCR-2-BL
PSV	377	Ar	SHT-2	3-	D	LAPD tank relief vent	relief valve	3 psid internal / 0.2 psid external	25 psig	Anderson Greenwood	9399C06SSTC
PRV	378	N2	SHT-2	7-	F	nitrogen to tank insulation	pressure regulator	0.5 - 5 psig	250 psig	Matheson	3702
PI	379	N2	SHT-2	7-	F	nitrogen to tank insulation	pressure indicator on regulator	0 - 100 psig	100 psig	US Gauge	0 - 100 psig gauge
PI	380	N2	SHT-2	7-	F	nitrogen to tank insulation	pressure indicator on regulator	0 - 10 psig	10 psig	Matheson	0 - 10 psig gauge
FO	381	Ar	SHT-2	4-	E	tank riser diffusion purge	orifice	3/32" (~Cv=0.2)	3500 psig	Swagelok	SS-8-VCR-2-BL
FCV	382	N2	SHT-2	7-	F	nitrogen to tank insulation	rotometer	30-240 sccm	100 psig	Dwyer Instruments	RMA-11-SSV
FO	383	Ar	SHT-2	2-	D	tank riser diffusion purge	orifice	3/32" (~Cv=0.2)	3500 psig	Swagelok	SS-8-VCR-2-BL
MV	384	Ar	SHT-2	5-	C	LAPD tank vapor isolation	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
HTR	385	Ar	SHT-2	5-	B	LAPD tank	tank heater #1	NA	external to process	Watlow	K020100C3-0009B
HTR	386	Ar	SHT-2	5-	B	LAPD tank	tank heater #2	NA	external to process	Watlow	K020100C3-0009B
HTR	387	Ar	SHT-2	4-	B	LAPD tank	tank heater #3	NA	external to process	Watlow	K020100C3-0009B
HTR	388	Ar	SHT-2	4-	B	LAPD tank	tank heater #4	NA	external to process	Watlow	K020100C3-0009B
HTR	389	Ar	SHT-2	4-	B	LAPD tank	tank heater #5	NA	external to process	Watlow	K020100C3-0009B
HTR	390	Ar	SHT-2	4-	B	LAPD tank	tank heater #6	NA	external to process	Watlow	K020100C3-0009B
HTR	391	Ar	SHT-2	4-	B	LAPD tank	tank heater #7	NA	external to process	Watlow	K020100C3-0009B
HTR	392	Ar	SHT-2	4-	B	LAPD tank	tank heater #8	NA	external to process	Watlow	K020100C3-0009B
HTR	393	Ar	SHT-2	4-	B	LAPD tank	tank heater #9	NA	external to process	Watlow	K020100C3-0009B
HTR	394	Ar	SHT-2	4-	B	LAPD tank	tank heater #10	NA	external to process	Watlow	K020100C3-0009B
HTR	395	Ar	SHT-2	4-	B	LAPD tank	tank heater #11	NA	external to process	Watlow	K020100C3-0009B
HTR	396	Ar	SHT-2	5-	B	LAPD tank	tank heater #12	NA	external to process	Watlow	K020100C3-0009B
HTR	397	Ar	SHT-2	5-	B	LAPD tank	tank heater #13	NA	external to process	Watlow	K020100C3-0009B
HTR	398	Ar	SHT-2	5-	B	LAPD tank	tank heater #14	NA	external to process	Watlow	K020100C3-0009B
HTR	399	Ar	SHT-2	3-	B	LAPD tank	tank heater #15	NA	external to process	Watlow	K020100C3-0009B
HTR	400	Ar	SHT-2	4-	B	LAPD tank	tank heater #16	NA	external to process	Watlow	K020100C3-0009B
HTR	401	Ar	SHT-2	4-	B	LAPD tank	tank heater #17	NA	external to process	Watlow	K020100C3-0009B
HTR	402	Ar	SHT-2	4-	B	LAPD tank	tank heater #18	NA	external to process	Watlow	K020100C3-0009B
HTR	403	Ar	SHT-2	4-	B	LAPD tank	tank heater #19	NA	external to process	Watlow	K020100C3-0009B
HTR	404	Ar	SHT-2	4-	B	LAPD tank	tank heater #20	NA	external to process	Watlow	K020100C3-0009B
HTR	405	Ar	SHT-2	4-	B	LAPD tank	tank heater #21	NA	external to process	Watlow	K020100C3-0009B
HTR	406	Ar	SHT-2	4-	B	LAPD tank	tank heater #22	NA	external to process	Watlow	K020100C3-0009B
HTR	407	Ar	SHT-2	3-	B	LAPD tank	tank heater #23	NA	external to process	Watlow	K020100C3-0009B
HTR	408	Ar	SHT-2	3-	B	LAPD tank	tank heater #24	NA	external to process	Watlow	K020100C3-0009B
TE	409	Ar	SHT-2	5-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	410	Ar	SHT-2	5-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	411	Ar	SHT-2	5-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	412	Ar	SHT-2	4-	C	LAPD tank (midpoint)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
TE	413	Ar	SHT-2	4-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	414	Ar	SHT-2	4-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
MV	415	N2	SHT-2	7-	F	nitrogen to tank insulation	manual valve	NA	1000 psig	Swagelok	B-4HK
FCV	417	N2	SHT-2	7-	F	nitrogen to tank insulation	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
TE	418	Ar	SHT-2	4-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	419	Ar	SHT-2	4-	C	LAPD tank (midpoint	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	420	Ar	SHT-2	4-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	421	Ar	SHT-2	4-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	422	Ar	SHT-2	4-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	423	Ar	SHT-2	3-	C	LAPD tank (midpoint)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
MV	427	Ar	SHT-2	6-	C	LAPD tank level	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	428	Ar	SHT-2	4-	D	LAPD tank sample line	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
FO	429	Ar	SHT-2	3-	D	tank riser diffusion purge	orifice	3/32" (~Cv=0.2)	3500 psig	Swagelok	SS-8-VCR-2-BL
FO	430	Ar	SHT-2	2-	D	tank riser diffusion purge	orifice	3/32" (~Cv=0.2)	3500 psig	Swagelok	SS-8-VCR-2-BL
PI	431	Ar	SHT-2	6-	E	tank pressure makeup	pressure indicator	vac - 150 psig	150 psig	US Gauge	vac - 150 psig pressure gauge
AV	432	Ar	SHT-2	6-	E	tank pressure makeup	automatic valve	NA	1000 psig	Swagelok	SS-6UW-V19-TF-6C
SV	432	Ar	SHT-2	6-	E	AV-432-Ar	solenoid valve	NA	150 psig	ASCO	EF8327G041
MV	433	Ar	SHT-2	5-	E	tank pressure makeup	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
MV	434	Ar	SHT-2	4-	F	LAPD tank vent to condenser	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
PI	435	Ar	SHT-2	4-	F	LAPD tank vent to condenser	manual valve	vac - 60 psig	60 psig	Ashcroft	25-1009SWXVKLL
MV	436	Ar	SHT-2	3-	E	bellows pump isolation	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
MV	437	Ar	SHT-2	2-	E	vent purge bellows pump sample	manual valve	NA	375 psig	Carten	MD-250
MV	438	Ar	SHT-2	2-	E	vent purge bellows pump discharge	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
TE	439	Ar	SHT-2	3-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	440	Ar	SHT-2	3-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	441	Ar	SHT-2	3-	C	LAPD tank (midpoint)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	442	Ar	SHT-2	3-	B	LAPD tank (base)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	443	Ar	SHT-2	3-	C	LAPD tank (top - L)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	444	Ar	SHT-2	4-	C	LAPD tank (top - E)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	445	Ar	SHT-2	4-	C	LAPD tank (top -C)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	446	Ar	SHT-2	5-	C	LAPD tank (top - A)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	447	Ar	SHT-2	5-	C	LAPD tank (top - B)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
TE	448	Ar	SHT-2	3-	C	LAPD tank (top - D)	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
FCV	449	N2	SHT-2	7-	F	phase separator insulaton purge	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
SV	450	N2	SHT-2	6-	F	liq N2 from phase separator condenser coil #1	solenoid valve	NA	300 psig	Magnatrol	14L42, 24 VDC
FCV	451	N2	SHT-2	7-	F	nitrogen to tank insulation	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
FCV	452	N2	SHT-2	7-	F	nitrogen to tank insulation	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
FCV	453	N2	SHT-2	7-	E	nitrogen to tank insulation	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
FCV	454	N2	SHT-2	7-	E	nitrogen to tank insulation	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
MV	455	Ar	SHT-2	4-	D	LAPD nozzle ar impurity purge vent	manual valve	NA	375 psig	Carten	MD-250
MV	456	Ar	SHT-2	4-	D	LAPD nozzle ar impurity purge vent	manual valve	NA	375 psig	Carten	MD-250
MV	457	Ar	SHT-2	3-	E	LAPD nozzle ar impurity purge vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
MV	458	Ar	SHT-2	4-	E	LAPD nozzle ar impurity purge vent	manual valve	NA	2500 psig	Swagelok	SS-12UAW-TW
MV	459	Ar	SHT-2	3-	E	LAPD nozzle ar impurity purge vent	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
PI	460	Ar	SHT-2	3-	E	bellows pump suction	local pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ P/N 50328794
MV	461	Ar	SHT-2	3-	E	bellows pump suction	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
MV	462	Ar	SHT-2	3-	E	bellows pump suction metering valve	manual valve	NA	700 psig	Swagelok	SS-4BMRW-TW
PI	463	Ar	SHT-2	3-	E	bellows pump suction	local pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ P/N 50328794
MV	464	Ar	SHT-2	2-	E	bellows pump dishcarge	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
MV	465	Ar	SHT-2	5-	F	condenser liquid to pump suction	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8122
MV	466	Ar	SHT-2	4-	F	vapor from tank to condenser	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8131
FCV	467	N2	SHT-2	7-	E	nitrogen to condenser insulation	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
PI	468	N2	SHT-2	5-	H	nitrogen to condenser	pressure indicator	0 - 100 psig	100 psig	US Gauge	162988
MV	469	N2	SHT-2	5-	G	nitrogen vent	manual valve	NA	1000 psig	Swagelok	B-4HK
MV	470	N2	SHT-2	6-	G	phase separator vent pressure	manual valve	NA	1000 psig	Swagelok	B-4HK
SP	471	Ar	SHT-2	6-	E	tank make up gas	particulate filter	NA	500 psig	McMASTER-CARR	4414K35
MV	472	Ar	SHT-2	5-	E	tank make up gas vent	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
SP	473	Har	SHT-3	7-	H	regeneration gas	particulate filter	NA	1177 psig	GKN and FNAL	GKN tool # 9111/2
SP	474	Ar	SHT-3	2-	F	liquid argon fill	particulate filter	NA	1177 psig	GKN and FNAL	GKN tool # 9111/1
SP	475	Ar	SHT-3	5-	B	liquid argon pump suction	particulate filter	NA	820 psig	GKN and FNAL	GKN tool # 9111/5
SP	476	Ar	SHT-3	7-	F	liquid return to tank	particulate filter	NA	820 psig	GKN and FNAL	GKN tool # 9111/5
MV	477	N2	SHT-2	7-	F	nitrogen purges	manual valve	NA	250 psig	Matheson	100-S
CV	478	Ar	SHT-2	6-	B	argon for tank purge	check valve	2 psi crack	3000 psig	Swagelok	6L-CW4VR8
SP	479	N2	SHT-2	6-	F	LN2 for condenser	Y-strainer (particulate filter)	NA	400 psig	McMASTER-CARR	44125K45 - 200 mesh
MV	480	Ar	SHT-2	6-	B	tank dp valving vent	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
MV	481	Ar	SHT-2	3-	E	purity monitor diffusion purge	manual valve	NA	1000 psig	Swagelok	SS-8BG-V51
MV	482	N2	SHT-2	7-	G	LN2 for condenser	manual valve	NA	1000 psig	Swagelok	B-4HK
MV	483	Ar	SHT-2	4-	D	breather isolation	manual valve	NA	15 psid	Varian	Bellows sealed conflat vacuum valve
SP	484	Ar	SHT-2	4-	D	tank atmospheric breather	particulate filter - sintered metal filter	NA	175 psig	McMASTER-CARR	440K56
MV	485	Ar	SHT-2	6-	D	tank pressure instrumentation valving	manual valve	NA	375 psig	Carten	MD 250
MV	486	Ar	SHT-2	6-	D	tank pressure instrumentation valving	manual valve	NA	375 psig	Carten	MD 250
PI	487	Ar	SHT-2	6-	D	tank vapor pressure	pressure indicator	0 - 35 psia	35 psig	Wallace & Tiernan	61A-1A-0035
MV	489	Ar	SHT-2	4-	F	condenser Argon side	manual valve	NA	1000 psig	Swagelok	SS-8BG-V51
PSV	491	Ar	SHT-2	6-	D	tank pressure instrumentation	relief valve	20 psig	2400 psig	Circle-Seal	5100-2MP

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
AE	492	V	SHT-2	2-	C	ambient	dewpoint transmitter	0-100% RH -40 to +80 C	external to process	Vaisala	HMT120KA1A2B12A1C0A
TE	493	N2	SHT-2	5-	G	N2 coil vent	100 ohm platinum RTD	NA	external to process	Minco	S651PDZ36A thermal ribbon
CV	494	N2	SHT-2	8-	F	N2 insulation purges	check valve	1/3 psia	3000 psig	Swagelok	B-4CP4-1/3
MV	495	N2	SHT-2	8-	F	N2 on/off to FCV	manual valve	NA	1000 psig	Swagelok	B-4HK
PI	496	Ar	SHT-2	4-	F	Pump cool down	pressure indicator	vac - 150 psig	150 psig	Ashcroft	25HPGG4FMVCRLXLL30IMV&150#
PSV	497	Ar	SHT-2	4-	F	Pump cool down trapped volume	relief valve	100 psig	2400 psig	Generant	CRV8-8V-K-100-PSI
MV	498	Ar	SHT-2	4-	F	Pump cool down	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
MV	499	Ar	SHT-2	4-	F	Pump cool down	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
PSV	500	Ar	SHT-3	7-	C	from LAPD tank to LAPD particulate filter before pump	relief valve	100 psig	2400 psig	Circle Seal	5100-2MP
AV	501	Ar	SHT-3	6-	B	from LAPD tank to LAPD particulate filter before pump (normally closed)	automatic valve (act'd by SV-641-N2	NA	165 psid	Eden Cryogenics	ECV-70-Y-20-B-VJ
SV	501	Ar	SHT-3	6-	B	AV-501-Ar	solenoid valve	NA	100 psig	ASCO	EF8327G041
MV	502	Ar	SHT-3	6-	B	LAPD condenser to LAPD particulate filter before pump	manual valve	NA	165 psid	Eden Cryogenics	EVC-60-Y-10-B-VJ
SC	504	Ar	SHT-3	5-	B	argon pump	motor speed control	NA	external to process	Toshiba	VFS11-4007PL-WN(r5)
PT	505	Ar	SHT-3	5-	B	argon pump vacuum jacket	pressure transmitter	0 - 1 Torr	1 atm	Granville-Phillips	275851-EU
MV	506	Ar	SHT-3	5-	C	pressure differential line on pump	manual valve	NA	375 psig	Carten	MD 250
DPT	507	Ar	SHT-3	5-	C	pressure differential across pump	pressure differential transmitter	0-100 psid	500 psi	GP:50	316DPJLC
MV	508	Ar	SHT-3	5-	B	pressure differential line on pump	manual valve	NA	375 psig	Carten	MD 250
PI	509	Ar	SHT-3	5-	C	pressure differential line on pump	local pressure indicator	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
PT	510	Ar	SHT-3	5-	C	pressure differential line on pump	pressure transmitter	0-250 psia	250 psia	Setra	2251250PAD41106
MV	511	Ar	SHT-3	4-	B	pressure differential line on pump	manual valve	NA	375 psig	Carten	MD 250
MV	512	Ar	SHT-3	4-	B	pump dishcharge	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
MV	513	Har	SHT-3	4-	F	regen gas to O2 filter	manual valve	NA	2500 psig	Swagelok	SS-12UAW-TW
MV	514	Ar	SHT-3	4-	B	from argon pump to flow transmitter, pump isolation	manual valve	NA	165 psig	Eden Cryogenics	BC-02146-8101
MV	516	Ar	SHT-3	3-	C	from argon pump to LAPD tank / filter bypass	manual valve	NA	165 psig	Eden Cryogenics	BC-02146-8122
PSV	517	Ar	SHT-3	6-	C	liquid argon from tank and condenser to particulate filter before pump	relief valve	100 psig	2400 psig	Circle Seal	5100-4MP
MV	527	Ar	SHT-3	3-	D	argon filtration	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PSV	531	Ar	SHT-3	3-	E	from argon pump to first filter	relief valve	100 psig	2400 psig	Circle Seal	5100-4MP
CV	532	Ar	SHT-3	3-	D	vapor recirculation	check valve	2 psi crack	3000 psig	Swagelok	6L-CW4VR8
PI	533	Har	SHT-3	7-	H	regen gas from heater to filters	local pressure indicator	vac - 150 psig	150 psig	US Gauge	FNAL stock item 1050-003500
PT	534	Har	SHT-3	7-	H	regen gas from heater to filters	pressure transmitter	0 - 100 psig	300 psig	Setra	C206, 100 psig, top mounted bayonet
MV	535	Har	SHT-3	7-	H	regen gas from heater to filters	manual valve	NA	1000 psig	Sharpe	84-6-6-P-G-SW
MV	539	Har	SHT-3	6-	H	regen gas to filter one	manual valve	NA	1000 psig	Sharpe	84-6-6-P-G-SW
MV	540	Ar	SHT-3	4-	F	regen gas to filter one	manual valve	NA	2500 psig	Swagelok	SS-12UAW-TW
MV	541	Ar	SHT-3	3-	F	filter one sample connection	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
TE	542	Ar	SHT-3	4-	G	regen gas to molecular sieve	Type K TC	NA	100 psig	Omega	TC-K-NPT-G-72
PSV	543	Ar	SHT-3	1-	F	bulk liquid argon supply line	relief valve	100 psig	2400 psig	Circle-Seal	5180B-4M-100
MV	544	Ar	SHT-3	1-	F	bulk liquid argon supply line	manual valve	NA	600 psig	CPC-Cryolab	ES4-088-TPG standard length bonnet, 1", NPT, globe body
PI	545	Ar	SHT-3	1-	F	bulk liquid argon supply line	local pressure indicator	vac - 150 psig	150 psig	Ashcroft	25HPGG4FMVCRLXLL30IMV&150#
MV	547	Ar	SHT-3	2-	F	bulk liquid argon supply line	manual valve	NA	600 psig	CPC-Cryolab	ES4-088-TPG standard length bonnet, 1", NPT, globe body
PSV	548	Ar	SHT-3	2-	F	bulk liquid argon supply line	relief valve	100 psig	2400 psig	Circle-Seal	5180B-4M-100
MV	549	Ar	SHT-3	2-	F	bulk liquid argon supply line	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8122
MV	550	Ar	SHT-3	3-	D	liquid recirculation mole sieve input	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PT	551	Ar	SHT-3	3-	D	liquid recirculation mole sieve input	pressure transmitter	0 - 500 psia	500 psia	Setra	2251250PAD41106
PI	552	Ar	SHT-3	3-	D	liquid recirculation mole sieve input	local pressure indicator	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
MV	553	Ar	SHT-3	2-	F	line from pump and bulk argon suppy to first filter	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8129
MV	554	Ar	SHT-3	4-	F	filter one to filter two	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
AV	557	Ar	SHT-3	6-	F	filter three to purity monitor	automatic valve (act'd by SV-557-Ar)	NA	165 psid	Eden Cryogenics	BC-02146-8119
SV	557	Ar	SHT-3	6-	F	AV-557-Ar	solenoid valve	NA	150 psig	ASCO	EF8327G041
MV	559	Ar	SHT-3	6-	E	filter loop vent to argon vaporizer and atmosphere	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8129
MV	560	Ar	SHT-3	7-	G	purity monitor vent to vent compressor	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
FCV	562	Ar	SHT-3	7-	G	purity monitor vent	automatic valve (act'd by SV562-Ar)	NA	1000 psig	Swagelok	SS-6UW-V19-TF-6C
SV	562	Ar	SHT-3	7-	G	FCV-552-Ar	solenoid valve	NA	150 psig	ASCO	EF8327G041
MV	563	Ar	SHT-3	6-	C	liquid argon from tank and condenser to particulate filter before pump	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
PSV	564	Ar	SHT-3	3-	B	from argon pump to first filter	relief valve	100 psig	2400 psig	Circle Seal	5100-4MP
MV	565	Har	SHT-3	4-	G	O2 filter regen vent to water analyzer	manual valve	NA	2500 psig	Swagelok	SS-12UAW-TW
AE	566	Har	SHT-3	2-	G	O2 filter regeneration vent	Dewpoint meter	-80 to +20 C	290 psia	Vaisala	DMT242A1A1A1B
PSV	568	Ar	SHT-3	4-	G	filter two	relief valve	100 psig	400 psig	Rockwood Swendeman	710NBEF-A
MV	569	Ar	SHT-3	4-	G	filter two	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PT	570	Ar	SHT-3	4-	G	oxygen filter	pressure transmitter	0-250 psia	250 psia	Setra	2251250PAD41106
PI	571	Ar	SHT-3	4-	G	filter two	local pressure indicator	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
MV	572	Ar	SHT-3	4-	F	filter two sample connection		NA	160 psig	Swagelok	6LVV-DPBW4-P
MV	573	Har	SHT-3	3-	G	filter one to anlyzer	manual valve	NA	250 psig	Swagelok	SS-12UAW-TW
TE	574	Har	SHT-3	5-	G	regen gas to oxygen filter	Type K TC	NA	2500 psig	Omega	TC-K-NPT-G-72
AE	576	Har	SHT-3	2-	G	molecular sieve regeneration vent	Dewpoint meter	-80 to +20 C	290 psia	Vaisala	DMT242A1A1A1B
LT	586	Ar	SHT-3	6-	G	purity monitor liquid level	capacitance probe	0 - 44.6 inches	100 psig	American Magnetics	Model 185 Liquid Level Monitor
PSV	587	Ar	SHT-3	6-	G	purity monitor	relief valve	100 psig	400 psig	Rockwood Swendeman	710NBEF-A
PI	589	Ar	SHT-3	6-	H	purity monitor	local pressure indicator	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
PT	590	Ar	SHT-3	6-	H	purity monitor	pressure transmitter	0 - 250 psia	250 psia	Setra	2251250PAD41106
FCV	592	Har	SHT-3	7-	H	regen gas from heater to filters	Variable Area Flowmeter	0 - 1,000 SCFH	100 psig	Dwyer Instruments	RMC-106-SSV
MV	593	Ar	SHT-3	6-	G	purity monitor to LAPD tank	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
MV	594	Ar	SHT-3	3-	B	from argon pump to first filter, flowmeter isolation	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
FT	595	Ar	SHT-3	3-	B	from argon pump to first filter	coriolis flow transmitter	0 - 15 GPM	285 psig	Emerson Process Management	Micro Motion flowmeter CMF100M328NQBUEZZZ and transmitter 1700R12ABUEZZZ
MV	596	Ar	SHT-3	3-	B	from argon pump to first filter	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
MV	597	Ar	SHT-3	3-	B	from argon pump to first filter, blowdown	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
PSV	598	Ar	SHT-3	4-	B	from argon pump to first filter (trapped volume relief)	relief valve	100 psig	1000 psig	Circle Seal	5100-4MP
MV	599	Ar	SHT-3	3-	B	from argon pump to first filter, flowmeter bypass	manual valve	NA	2400 psig	Eden Cryogenics	BC-02146-8101
PSV	601	Ar	SHT-3	3-	F	filter one	relief valve	100 psig	400 psig	Rockwood Swendeman	710NBEF-A
MV	602	Ar	SHT-3	3-	F	filter one	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PT	603	Ar	SHT-3	3-	G	molecular sieve	pressure transmitter	0-250 psia	250 psig	Setra	2251250PAD41106
PI	604	Ar	SHT-3	3-	G	filter one	local pressure indicator	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
FCVE	606	Ar	SHT-3	4-	D	makeup argon gas to pump loop	flow control valve	0 - 10,000 sccm	150 psig	MKS	1480
CV	607	Ar	SHT-3	3-	D	makeup argon gas to pump loop	check valve	1 / 3 psi crack	150 psig	Hylok	CVWBVM-4-SM6L
MV	608	Ar	SHT-3	3-	D	makeup argon gas to pump loop	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	609	Ar	SHT-3	3-	D	makeup argon gas to pump loop	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	610	Ar	SHT-3	3-	D	from vent compressor to pump loop	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX
TE	611	Ar	SHT-3	8-	E	filter loop vent to argon vaporizer and atmosphere	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-4-E-SL RTD
HTR	612	Har	SHT-3	6-	H	regen gas from heater to filters	Circulation heater	NA	100 psig	Omega	AHPF-122
PSV	615	Ar	SHT-3	8-	F	liquid return to tank	relief valve	100 psig	external to process	Circle Seal	5100-4MP
SP	620	Ar	SHT-3	1-	F	bulk liquid argon supply line	y-strainer	NA	400 psig	McMASTER-CARR	44125K45 - 200 mesh
TE	621	Ar	SHT-3	3-	F	molecular sieve	100 ohm platinum RTD	NA	400 psig	Omega	PR-18-2-100-1/4-6-E-SL RTD
TE	622	Ar	SHT-3	3-	F	molecular sieve	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-4-E-SL RTD
TE	623	Ar	SHT-3	3-	F	molecular sieve	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-6-E-SL RTD
TE	624	Ar	SHT-3	3-	F	molecular sieve	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-4-E-SL RTD
TE	625	Ar	SHT-3	3-	F	molecular sieve	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-6-E-SL RTD
TE	626	Ar	SHT-3	4-	F	oxygen filter	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-6-E-SL RTD
TE	627	Ar	SHT-3	4-	F	oxygen filter	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-4-E-SL RTD
TE	628	Ar	SHT-3	4-	F	oxygen filter	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-6-E-SL RTD
TE	629	Ar	SHT-3	4-	F	oxygen filter	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-4-E-SL RTD
TE	630	Ar	SHT-3	4-	F	oxygen filter	100 ohm platinum RTD	NA	external to process	Omega	PR-18-2-100-1/4-6-E-SL RTD
MV	633	Ar	SHT-3	6-	B	LAPD TANK TO Argon vaporizer	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
HTR	634	Har	SHT-3	6-	H	regen gas from heater to filters	Circulation heater	NA	165 psid	Omega	AHPF-122
TE	635	Har	SHT-3	6-	H	regen gas heater (gas flow)	Type K TC	NA	100 psig	Omega	TC-K-NPT-G-72
TE	636	Har	SHT-3	6-	H	regen gas heater (heater surface)	Type K TC	NA	100 psig	Watlow	75XKFGA120A
TE	637	Har	SHT-3	6-	H	regen gas heater (gas flow)	Type K TC	NA	external to process	Omega	TC-K-NPT-G-72
TE	638	Har	SHT-3	7-	H	regen gas heater (gas flow)	Type K TC	NA	100 psig	Omega	TC-K-NPT-G-72
TE	639	Har	SHT-3	6-	H	regen gas heater (heater surface)	Type K TC	NA	100 psig	Watlow	75XKFGA120A
TE	640	Har	SHT-3	6-	H	regen gas heater (gas flow)	Type K TC	NA	external to process	Omega	TC-K-NPT-G-72
PSV	650	Ar	SHT-3	7-	B	liquid line to pump	relief valve	100 psig	150 psig	Circle Seal	5100-2MP
PI	651	Ar	SHT-3	7-	B	liquid line to pump	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
MV	652	Ar	SHT-3	7-	B	liquid line to pump	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
PI	653	Ar	SHT-3	7-	C	condenser to pump suction	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
MV	654	Ar	SHT-3	7-	C	condenser to pump suction	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
PI	655	Ar	SHT-3	6-	C	liquid line to pump	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
DPT	656	Ar	SHT-3	5-	C	liquid line to pump across filter	differential pressure transmitter	0 - 5 psid	160 psig	Setra	C239
PI	657	Ar	SHT-3	5-	C	liquid line to pump	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
MV	658	Ar	SHT-3	5-	C	liquid line to pump	manual valve	NA	375 psig	Carten	MD 250
MV	659	Ar	SHT-3	6-	B	liquid line to pump	manual valve	NA	375 psig	Carten	MD 250
MV	660	Ar	SHT-3	5-	B	liquid line to pump	manual valve	NA	375 psig	Carten	MD 250
MV	661	Ar	SHT-3	4-	C	liquid line pump discharge	manual valve	NA	375 psig	Carten	MD 250
TE	662	Ar	SHT-3	5-	B	liquid pump temperature	100 ohm platinum RTD	NA	375 psig	Minco	S651PDZ36A thermal ribbon
PSV	663	Ar	SHT-3	4-	C	pump discharge trapped volume relief	relief valve	100 psig	2400 psig	Circle Seal	5100-4MP
FCV	664	N2	*SHT-2*	7-	E	nitrogen purge to liquid argon flowmeter foam insulaton	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
PI	665	Ar	SHT-3	3-	B	liquid argon flowmeter inlet pressure	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
PSV	666	V	SHT-3	5-	B	tank to pump vacuum jacket relief	relief valve (vacuum pumpout)	~ 0 psig	160 psig	CVI	V-1046-31 (spring removed)
LT	667	Ar	489659	4-	C	Liquid argon supply trailer liquid level	Level transmitter	0 - 100 "H2O		Ashcroft C	C1
MV	667	Ar	SHT-3	5-	E	future filter bypass isolation	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
PT	668	V	SHT-3	3-	F	molecular sieve vacuum	pressure transmitter	0 - 1 Torr	1 atm	Granville-Phillips	275851-EU
PT	669	V	SHT-3	4-	F	Cu filter vacuum	pressure transmitter	0 - 1 Torr	1 atm	Granville-Phillips	275851-EU
PSV	670	V	SHT-3	3-	F	molecular sieve vacuum	parallel plate relief	~0.25 psid	1 atm	Eden Cryogenics	Eden dwg # BC-02128-5815
PSV	671	V	SHT-3	4-	F	oxygen filter vacuum	parallel plate relief	~0.25 psid	1 atm	Eden Cryogenics	Eden dwg # BC-02128-5815
PSV	672	V	SHT-3	6-	F	inline purity monitor vacuum	parallel plate relief	~0.64 psid	1 atm	Fermilab	MB-106391
PI	673	Ar	SHT-3	8-	F	liquid return to tank	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
PT	673	Ar	489659	4-	C	Liquid argon supply trailer	pressure transmitter	0 - 100 psig	100 psig	Ashcroft	Duratran #2279
MV	674	Ar	SHT-3	6-	F	inline purity monitor bypass	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
MV	675	Ar	SHT-3	7-	F	liquid return to tank	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
MV	676	Ar	SHT-3	6-	E	filter bypass	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
MV	677	Ar	SHT-3	6-	F	inline purity monitor bypass	manual valve	NA	1000 psig	Swagelok	SS-8BG-TW
PI	678	Ar	SHT-3	6-	F	inline purity monitor bypass	pressure gauge	vac - 160 psig	160 psig	WIKA	230.15 2" P/N 50328808
PI	680	Ar	SHT-3	2-	F	Lar supply	local pressure indicator	vac - 150 psig	150 psig	Ashcroft	25HPGG4FMVCRLXLL30IMV&150#
MV	681	Ar	SHT-3	2-	F	Lar supply	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
FCV	682	N2	*SHT-2*	7-	E	nitrogen purge - spare	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
PSV	683	Ar	SHT-3	6-	F	liquid return to tank	relief valve	100 psig	2400 psig	Circle Seal	5100-4MP
PI	684	Har	SHT-3	7-	H	regeneration gas heater inlet	pressure gauge	vac - 150 psig	150 psig	US Gauge	FNAL stock item 1050-003500
MV	685	Har	SHT-3	7-	H	regeneration gas heater inlet	manual valve	NA	1000 psig	Sharpe	84-6-6-P-G-SW
MV	686	Har	SHT-3	3-	G	regeneration vent drain	manual valve	NA	1000 psig	Swagelok	B-4HK-2
MV	687	Har	SHT-3	3-	G	regeneration vent drain	manual valve	NA	1000 psig	Swagelok	B-4HK-2
MV	688	Ar	SHT-3	3-	B	post pump Lar trapped volume	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
MV	689	Ar	SHT-3	3-	B	post pump Lar trapped volume	manual valve	NA	300 psig	Swagelok	6L-ELD8-CCXX

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
PI	690	Ar	SHT-3	3-	B	post pump Lar trapped volume	pressure gauge	vac - 150 psig	150 psig	Ashcroft	25HPGG4FMVCRLXLL30IMV&150#
MV	691	Ar	SHT-3	7-	F	tank liquid return trapped volume	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
MV	692	Ar	SHT-3	7-	F	tank liquid return trapped volume	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PSV	693	Ar	SHT-3	7-	E	trapped volume relief	relief valve	100 psig	2400 psig	Generant	CRV8-8V-K-100-PSI
MV	694	Ar	SHT-3	7-	G	inline purity monitor	manual valve	NA	100 psig	Varian	951-5017
MV	695	Ar	SHT-3	7-	G	liquid return to tank	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
PSV	696	Ar	SHT-3	7-	G	cool pump cool down valving	relief valve	100 psig	2400 psig	Generant	CRV8-8V-K-100-PSI
PI	697	Ar	SHT-3	8-	E	vaporizer outlet	pressure gauge	0 - 15 psig	15 psig	USG	NA
PI	698	Ar	SHT-3	7-	G	pump discharge	pressure gauge	vac - 150 psig	150 psig	Ashcroft	25HPGG4FMVCRLXLL30IMV&150#
SV	699	Ar	SHT-3	8-	E	LAr electric vaporizer	solenoid valve	NA	500 psig	included with vaporizer package	NA
TS	700	Ar	SHT-3	8-	E	LAr electric vaporizer	temperature switch	- 20 F	500 psig	included with vaporizer package	NA
HTR	701	Ar	SHT-3	8-	E	LAr electric vaporizer	heater	NA	500 psig	included with vaporizer package	NA
AE	702	Har	SHT-3	3-	G	Regeneration gas vent	Hydrogen analyzer	0 - 10% H2	atm	Beacon	110
PT	703	Ar	SHT-3	6-	F	O2 filter discharge	pressure transmitter	0 - 250 psia	250 psia	Setra	2251250PAD41106
PT	704	Ar	SHT-3	8-	F	Tank side of return particulate filter	pressure transmitter	0 - 250 psia	250 psia	Setra	2251250PAD41106
SV	705	Har	SHT-3	7-	H	Regen gas to filters	solenoid valve	NA	100 psig	Asco	8210B054
SV	706	Har	SHT-3	7-	H	H2/Ar dilution shutoff	solenoid valve	NA	100 psig	Asco	8210B054
PI	707	Har	SHT-3	3-	H	O2 filter regeneration vent H2 analyzer	pressure gauge	vac - 30 psig	30 psig	USG	FNAL stock item 1050-002500
MV	708	Har	SHT-3	3-	H	O2 filter regeneration vent H2 analyzer	manual valve	NA	1000 psig	Swagelok	B-4HK
FCV	709	Har	SHT-3	3-	H	O2 filter regeneration vent H2 analyzer	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
MV	710	Har	SHT-3	3-	H	H2 analyzer	manual valve	NA	1000 psig	Swagelok	B-4HK
FCV	711	Har	SHT-3	3-	H	H2 analyzer	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
MV	712	Har	SHT-3	3-	H	H2 analyzer	manual valve	NA	1000 psig	Swagelok	B-4HK
FCV	713	Har	SHT-3	3-	H	H2 analyzer	rotometer	30-240 sccm	100 psig	Dwyer	RMA-11-SSV
FCV	714	Har	SHT-3	7-	H	H2/Ar dilution	rotometer	10 - 1000 SCFH	100 psig	Dwyer	RMC-102-SSV
PI	715	Har	SHT-3	7-	H	H2/Ar dilution	pressure gauge	vac - 150 psig	150 psig	US Gauge	FNAL stock item 1050-003500
MV	716	Har	SHT-3	7-	H	H2/Ar dilution	manual valve	NA	1000 psig	Swagelok	B-4HK
MV	717	Ar	SHT-3	5-	B	pump strainer vent	manual valve	NA	1000 psig	Swagelok	SS-4BG-V47
MV	718	Ar	SHT-3	4-	C	pump discharge cooldown	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
MV	719	Ar	SHT-3	4-	C	pump discharge	manual valve	NA	1000 psig	Swagelok	SS-8BG-V47
PSV	720	Ar	SHT-3	3-	C	pump discharge trapped volume relief	relief valve	100 psig	2400 psig	Generant	CRV8-8V-K-100-PSI
SP	721	Ar	SHT-3	5-	F	Post filter particulate	particulate filter	NA	820 psig	GKN and FNAL	GKN tool # 9111/5
FO	722	Ar	SHT-3	6-	F	inline purity monitor	orifice	3/8" (~Cv = 2)	NA	Fermilab	NA
MV	803	N2	SHT-4	6-	G	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
SP	804	N2	SHT-4	6-	G	gas analyzers	H2O filter	NA	350	Matheson	460 (housing) + 461 (cartridge)
MV	805	N2	SHT-4	5-	G	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	806	N2	SHT-4	5-	G	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
SP	807	N2	SHT-4	5-	G	gas analyzers	O2 filter	NA	150 psig	Airgas	Y40-RES0010K with Y40-RES0301 oxygen cartridge
MV	808	N2	SHT-4	5-	G	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	809	N2	SHT-4	6-	G	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	810	N2	SHT-4	6-	F	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
SP	811	N2	SHT-4	6-	F	gas analyzers	H2O filter	NA	350 psig	Matheson	460 (housing) + 461 (cartridge)
MV	812	N2	SHT-4	5-	F	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	813	N2	SHT-4	5-	F	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
SP	814	N2	SHT-4	5-	F	contaminant gas to analyzers	O2 filter	NA	150 psig	Airgas	Y40-RES0010K with Y40-RES0301 oxygen cartridge
MV	815	N2	SHT-4	5-	F	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
AE	819	V	SHT-4	2-	E	vicinity of LAPD tank	ODH O2 sensor	0-25% O2	atm	MSA	A-ULTIMAX-PL-A-14-03D2-0000-100
AE	820	V	SHT-4	2-	D	vicinity of LAPD tank	ODH O2 sensor	0-25% O2	atm	MSA	A-ULTIMAX-PL-A-14-03D2-0000-100
FS	821	V	SHT-4	1-	D	ODH blower inlet duct	pressure differential switch	100-1000 cm/sec	atm	Efector	SL5101
MV	822	Ar	SHT-3		F	analyzer pump input	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	827	N2	SHT-4	5-	F	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	828	N2	SHT-4	5-	G	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
PI	829	N2	SHT-4	5-	G	gas analyzers	pressure indicator	vac - 160 psig	160 psig	Wika	230.15-B-PV412-Z-WI-UZ-ZZZ ZZ
CV	830	N2	SHT-4	5-	F	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
CV	831	Ar	SHT-4	6-	F	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
MV	840	Ar	SHT-4	3-	F	gas analyzers	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	841	Ar	SHT-4	3-	F	gas analyzers	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PI	842	Ar	SHT-4	4-	F	gas analyzers	pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ
PT	843	Ar	SHT-4	4-	F	gas analyzers	pressure transmitter	0 - 100 psia	150 psig	Setra	2251100PAC411B1
PI	844	Ar	SHT-4	4-	F	gas analyzers	pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ
PT	845	Ar	SHT-4	4-	F	gas analyzers	pressure transmitter	0 - 100 psia	150 psig	Setra	2251100PAC411B1
PSV	846	Ar	SHT-4	4-	F	gas analyzers	relief valve	40 psig	2400 psig	Circle Seal	5100-2MP
CV	847	Ar	SHT-4	4-	F	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
MV	848	Ar	SHT-4	4-	F	gas analyzers	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
MV	849	Ar	SHT-4	4-	F	gas analyzers	manual valve	NA	250 psig	Swagelok	6LVV-DPBW4-P
PI	850	Ar	SHT-4	3-	F	gas analyzers	pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ
PCV	851	N2	SHT-4	3-	F	gas analyzers	pressure control valve	0 - 30 psig	300 psig	Matheson	9332-3-V4FF
EV	852	Ar	SHT-4	3-	F	gas analyzers	control valve	Cv max = 0.02	750 psig	Swagelok	SS-4BMG-V51 w/actuator (Custom part # OS-FERMI-004)
MV	853	Ar	SHT-4	3-	F	gas analyzers	manual valve	NA	1000 psig	Swagelok	SS-4BG-TW
AE	860	V	SHT-4	3-	D	gas analyzers	Dewpoint meter	-80 to +20 C	290 psia	Vaisala	DMT242A1A1A1B
AE	861	V	SHT-4	6-	C	gas analyzers	Dewpoint meter	-80 to +20 C	290 psia	Vaisala	DMT242A1A1A1B
MV	900	V	SHT-4	5-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	901	V	SHT-4	5-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	902	V	SHT-4	5-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250

Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
MV	903	V	SHT-4	6-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	904	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	905	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	906	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	907	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	908	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	909	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	910	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	911	V	SHT-4	6-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	912	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	913	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	914	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	915	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	916	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	917	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	918	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	919	V	SHT-4	6-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	920	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	921	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	922	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	923	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	924	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	925	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	926	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	927	V	SHT-4	6-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	928	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	929	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	930	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	931	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	932	V	SHT-4	5-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	933	V	SHT-4	5-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	934	V	SHT-4	5-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	935	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	936	V	SHT-4	4-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	937	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	938	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	939	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	940	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	941	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	942	V	SHT-4	5-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	943	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	944	V	SHT-4	4-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	945	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	946	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	947	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	948	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	949	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	950	V	SHT-4	5-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	951	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	952	V	SHT-4	4-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	953	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	954	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	955	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	956	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	957	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	958	V	SHT-4	5-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	959	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	960	V	SHT-4	4-	B	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	961	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	962	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	963	V	SHT-4	5-	A	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	964	V	SHT-4	6-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
MV	965	V	SHT-4	6-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
PE	966	V	SHT-4	6-	E	gas analyzers	pressure element	NA	~ 1 atm	Granville Phillips	275 Convectron Gauge
CV	967	V	SHT-4	6-	E	gas analyzers	check valve	2 psig	3000 psig	Circle Seal	249T14PP-2 psi
CV	968	V	SHT-4	6-	D	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
MV	969	V	SHT-4	6-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
CV	970	V	SHT-4	6-	C	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
PCV	971	V	SHT-4	6-	B	gas analyzers	pressure control valve	0 - 30 psig	300 psig	Matheson	9332-3-V4FF
PI	972	V	SHT-4	6-	B	gas analyzers	pressure indicator	30"-0-60 psig	60 psig	Matheson	supplied with regulator
CV	973	V	SHT-4	6-	B	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
PCV	974	V	SHT-4	4-	D	gas analyzers	pressure control valve	0 - 30 psig	300 psig	Matheson	9332-3-V4FF
PI	975	V	SHT-4	4-	D	gas analyzers	pressure indicator	30"-0-60 psig	60 psig	Matheson	supplied with regulator
CV	976	V	SHT-4	4-	D	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4

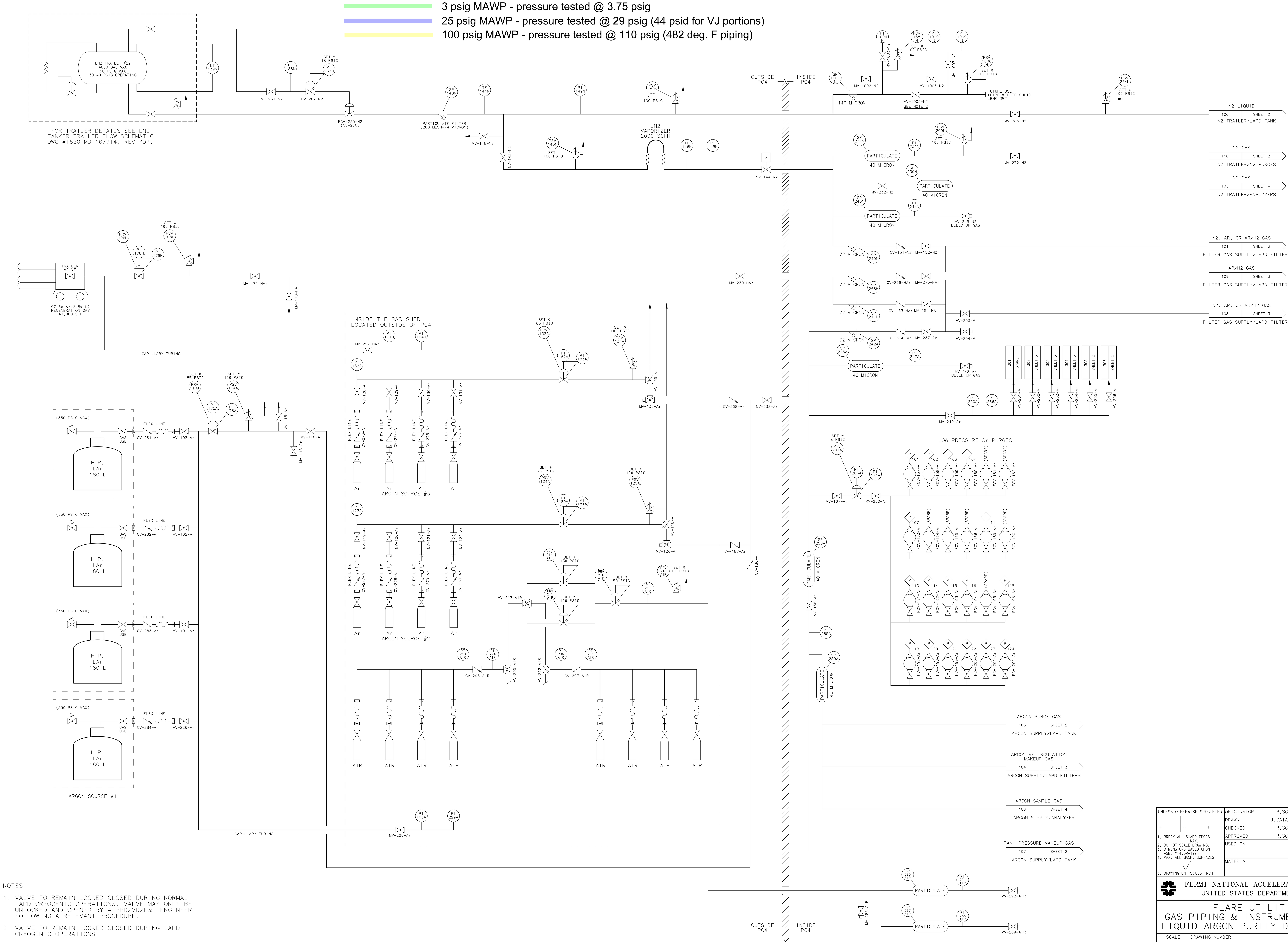
Instr Code	Tag #	Serv. Code	PID	GRID	LOC	Service Description	Instrument Type	Operating Range or Setpoint	Pressure Rating	Manufacturer	Model No.
CV	977	V	SHT-4	4-	C	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
MV	978	V	SHT-4	4-	C	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
PCV	979	V	SHT-4	4-	C	gas analyzers	pressure control valve	0 - 30 psig	300 psig	Matheson	9332-3-V4FF
PI	980	V	SHT-4	4-	C	gas analyzers	pressure indicator	30"-0-60 psig	60 psig	Matheson	supplied with regulator
CV	981	V	SHT-4	4-	C	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
PCV	982	V	SHT-4	4-	B	gas analyzers	pressure control valve	0 - 30 psig	300 psig	Matheson	9332-3-V4FF
PI	983	V	SHT-4	4-	B	gas analyzers	pressure indicator	30"-0-60 psig	60 psig	Matheson	supplied with regulator
CV	984	V	SHT-4	4-	B	gas analyzers	check valve	2 psig	3000 psig	Swagelok	6L-CW4FR4
AE	990	V	SHT-4	7-	D	gas analyzers	oxygen analyzer	0 - 2.5 ppm	125 psig	Tiger Optics	LaserTrace O2
AE	991	V	SHT-4	7-	C	gas analyzers	water analyzer	0 - 20 ppm	125 psig	Tiger Optics	HaloTrace H2O
AE	992	V	SHT-4	7-	B	gas analyzers	oxygen analyzer	0 - 50 ppm	30 psig	Delta-F	DF-310E
AE	993	V	SHT-4	4-	D	gas analyzers	nitrogen analyzer	0 - 100 ppm	30 psig	Servomex/Kontrol Analytik	K2001
AE	994	V	SHT-4	4-	D	gas analyzers	water analyzer	0 - 5 ppm	125 psig	Tiger Optics	LaserTrace H2O
AE	995	V	SHT-4	4-	B	gas analyzers	oxygen analyzer	0 - 100 ppm	30 psig	Delta-F	NanoTrace II DF-560
AE	996	V	SHT-4	4-	A	gas analyzers	oxygen analyzer	0 - 5000 ppm	30 psig	Delta-F	DF-310
MV	997	V	SHT-4	6-	E	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
PI	998	V	SHT-4	6-	E	gas analyzers	pressure indicator	vac - 60 psig	60 psig	Wika	230.15-B-PV352-Z-WI-UZ-ZZZ ZZ
MV	999	V	SHT-4	6-	D	gas analyzers	manual valve	NA	375 psig	Carten	MD-250
SP	1001	N2	SHT-1	3-	G	N2 liquid to LBNE 35T	particulate filter	NA	1400 psig	McMaster	4745K555
MV	1002	N2	SHT-1	3-	G	N2 liquid to LBNE 35T instrumentation	manual valve	NA	1000 psig	Swagelok	B-4HK2
MV	1003	N2	SHT-1	3-	G	N2 liquid to LBNE 35T instrumentation	manual valve	NA	1000 psig	Swagelok	B-4HK2
PI	1004	N2	SHT-1	3-	G	N2 liquid to LBNE 35T instrumentation	pressure indicator	vac - 150 psig	150 psig	US Gauge	FNAL STK 1050-003500
MV	1005	N2	SHT-1	3-	G	N2 liquid to LBNE 35T	manual valve	NA	870 psig	Worcester	1” #C4466 PM SW
MV	1006	N2	SHT-1	3-	G	N2 liquid to LBNE 35T instrumentation	manual valve	NA	1000 psig	Swagelok	B-4HK2
MV	1007	N2	SHT-1	3-	G	N2 liquid to LBNE 35T instrumentation	manual valve	NA	1000 psig	Swagelok	B-4HK2
PSV	1008	N2	SHT-1	3-	G	N2 liquid to LBNE 35T	relief valve	100 psig	2400 psig	Circle Seal	5100-4MP
PI	1009	N2	SHT-1	3-	G	N2 liquid to LBNE 35T instrumentation	pressure gauge	vac - 150 psig	150 psig	US Gauge	FNAL STK 1050-003500
PT	1010	N2	SHT-1	3-	G	N2 liquid to LBNE 35T	pressure transmitter	vac - 135 psig	135 psig	Setra	5161-135P-C-2M-11-B1-H
MV	5001	Ar	SHT-3	4-	A	LBNE 35T to filter (isolation)	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101
MV	5002	Ar	SHT-3	7-	F	LBNE 35T from filters (isolation)	manual valve	NA	165 psid	Eden Cryogenics	BC-02146-8101

M	MISC. REVISIONS MADE.	J.CATALANELLO	22-MAY-2012

				REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
F	MISC. REVISIONS MADE.	J.CATALANELLO / M.ADAMOWSKI	26-FEB-2010 / 26-FEB-2010	A	ADDED TAG NUMBERS TO VALVE TYPES	V. MAJDANSKI / R. SCHMITT	25FEB08 / 26FEB08
G	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	10-JAN-2011 / 12-JAN-2012	B	MOVE CONDENSOR OUTSIDE TANK	J.CATALANELLO / R.SCHMITT	07-DEC-2008 / 10-DEC-2008
H	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	10-JAN-2011 / 03-FEB-2011	C	MISC. REVISIONS MADE.	J.CATALANELLO / R.SCHMITT	23-DEC-2008 / 06-JAN-2009
J	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	23-FEB-2011 / 28-FEB-2011	D	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	17-NOV-2009 / 14-DEC-2009
K	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	04-MAR-2011 / 22-JUN-2011	E	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	17-NOV-2009 / 15-JAN-2010
L	MISC. REVISIONS MADE.	J.CATALANELLO / T.TOPE	11-JUL-2011 / 01-MAR-2012				

Piping covered in this note is highlighted according to the following key:

- 100 psig MAWP - pressure tested @ 111.5 psig (126.5 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig
- 60 psig MAWP - pressure tested @ 66 psig
- 3 psig MAWP - pressure tested @ 3.75 psig
- 25 psig MAWP - pressure tested @ 29 psig (44 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig (482 deg. F piping)



NOTES

1. VALVE TO REMAIN LOCKED CLOSED DURING NORMAL LAPD CRYOGENIC OPERATIONS. VALVE MAY ONLY BE UNLOCKED AND OPENED BY A PPD/MD/F&T ENGINEER FOLLOWING A RELEVANT PROCEDURE.
2. VALVE TO REMAIN LOCKED CLOSED DURING LAPD CRYOGENIC OPERATIONS.

UNLESS OTHERWISE SPECIFIED		
ORIGINATOR	R.SCHMITT	26-JUN-2007
DRAWN	J.CATALANELLO	07-DEC-2007
CHECKED	R.SCHMITT	12-DEC-2007
APPROVED	R.SCHMITT	12-DEC-2007

± ± ±

1. BREAK ALL SHARP EDGES MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL

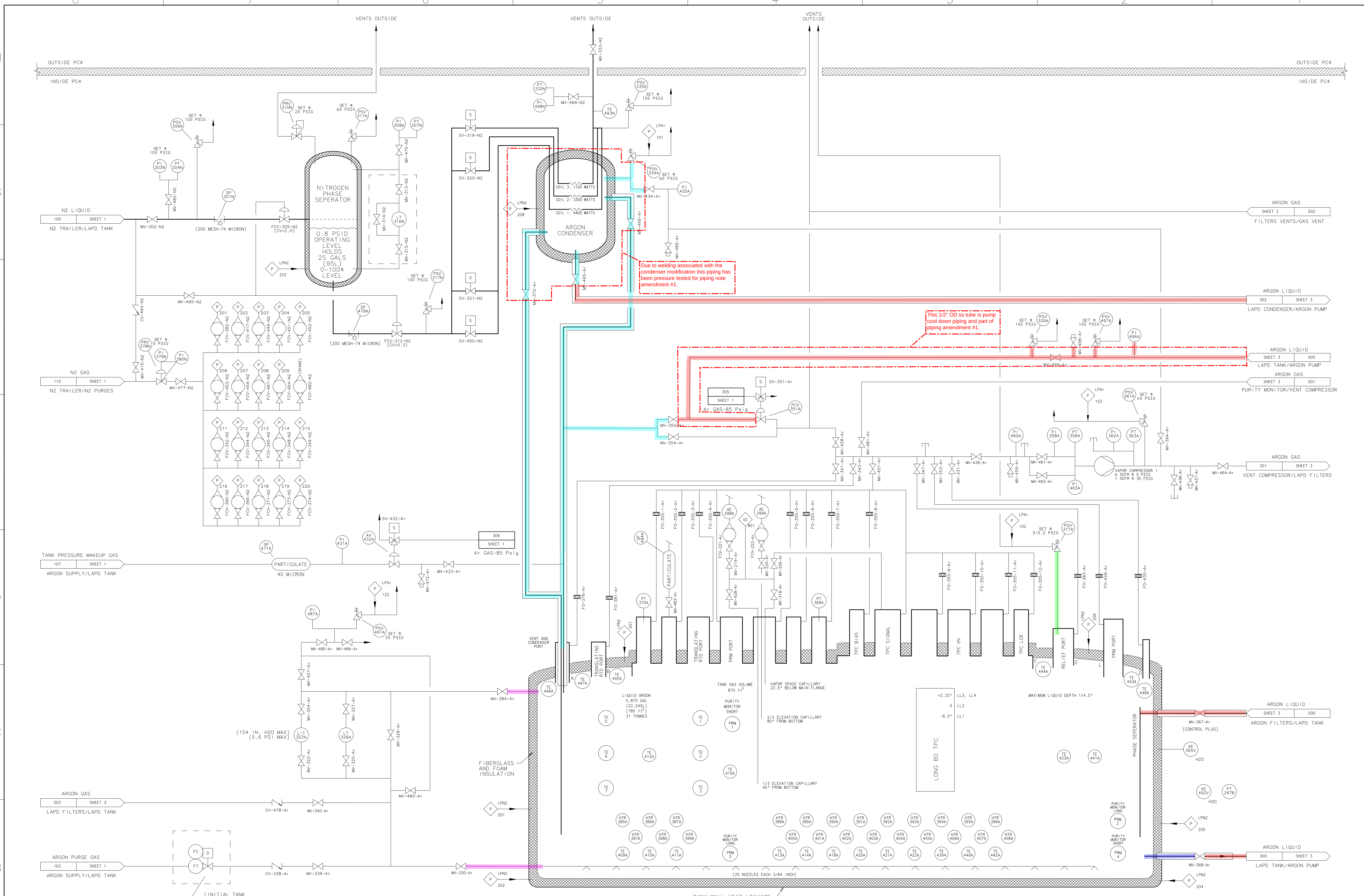
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE UTILITIES GAS PIPING & INSTRUMENT DIAGRAM LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	1 OF 4	M

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

Created: 08:12:02 on 18-10-12 (D-M-Y) By: catalan State: 1-INITIAL



Piping covered in this note is highlighted according to the following key:

- 100 psig MAWP - pressure tested @ 111.5 psig (126.5 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig
- 60 psig MAWP - pressure tested @ 66 psig
- 3 psig MAWP - pressure tested @ 3.75 psig
- 25 psig MAWP - pressure tested @ 29 psig (44 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig (482 deg. F piping)

UNLESS OTHERWISE SPECIFIED			
ORIGINATOR	R.SCHMITT	26-JUN-2007
DRAWN	J.CATALANELLO	07-DEC-2007
CHECKED	R.SCHMITT	12-DEC-2007
APPROVED	R.SCHMITT	12-DEC-2007

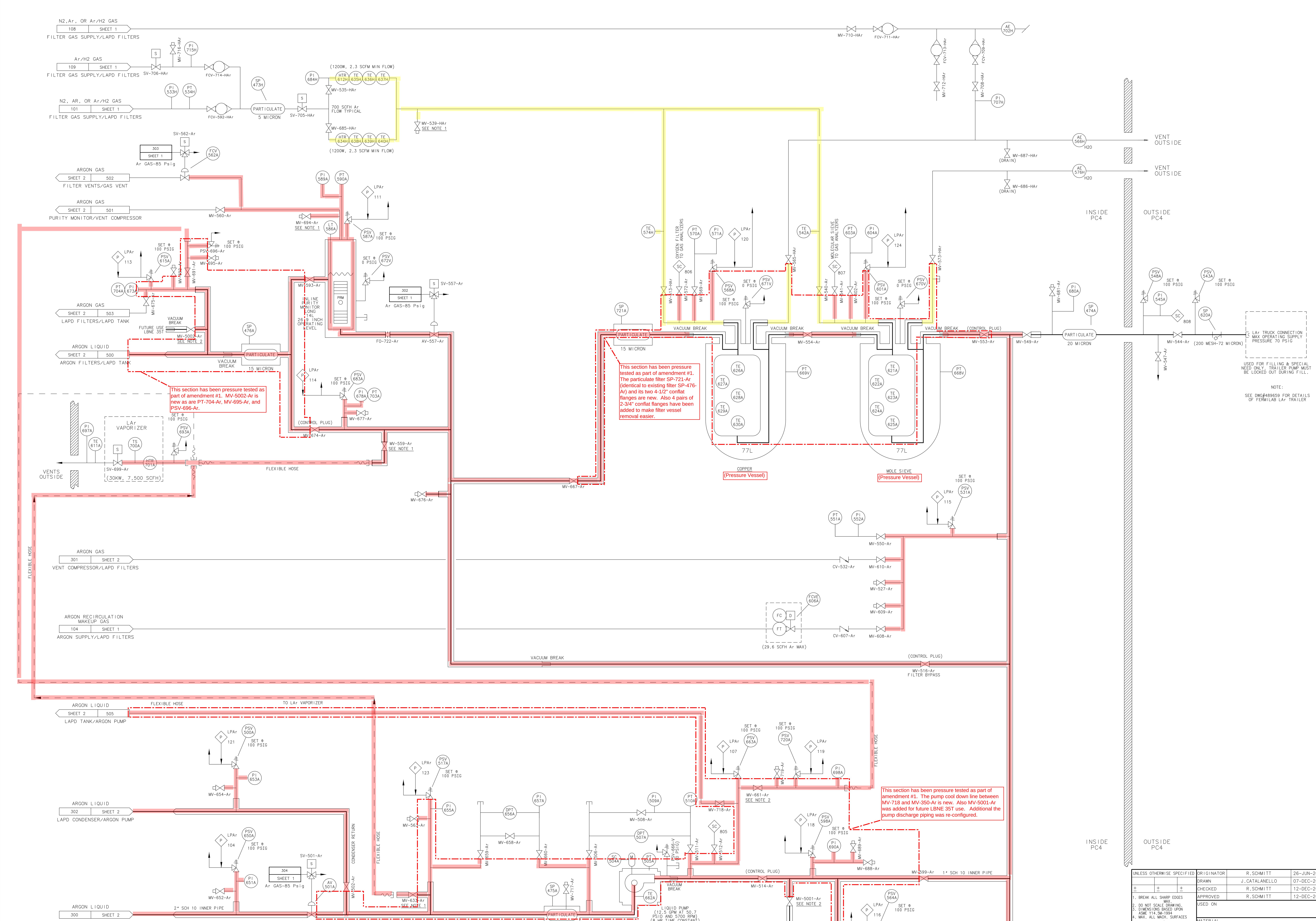
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE NONE | DRAWING NUMBER 3942.510-ME-444897 | SHEET 2 OF 4 | REV M

CREATED WITH: Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

Created: 08:12:10 on 18-10-12 (D-M-Y) By: catalan State: 1-INITIAL



Piping covered in this note is highlighted according to the following key:

- 100 psig MAWP - pressure tested @ 111.5 psig (126.5 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig
- 60 psig MAWP - pressure tested @ 66 psig
- 3 psig MAWP - pressure tested @ 3.75 psig
- 25 psig MAWP - pressure tested @ 29 psig (44 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig (482 deg. F piping)

NOTES

1. VALVE TO REMAIN LOCKED CLOSED DURING NORMAL LAPD CRYOGENIC OPERATIONS. VALVE MAY ONLY BE UNLOCKED AND OPENED BY A PPD/MD/F&T ENGINEER FOLLOWING A RELEVANT PROCEDURE.
2. VALVE TO REMAIN LOCKED CLOSED DURING LAPD CRYOGENIC OPERATIONS.

UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

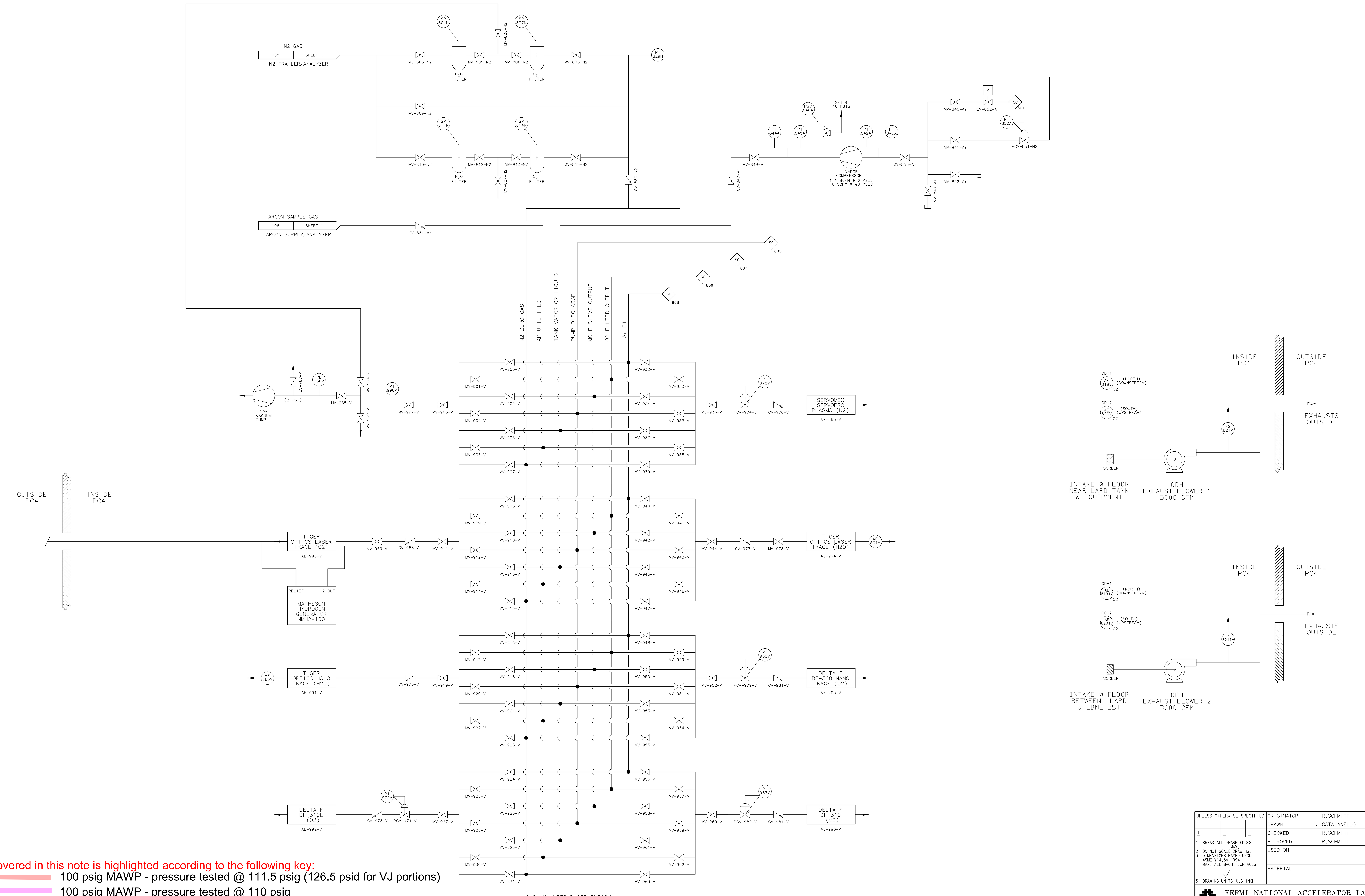
ORIGINATOR	R.SCHMITT	26-JUN-2007
DRAWN	J.CATALANELLO	07-DEC-2007
CHECKED	R.SCHMITT	12-DEC-2007
APPROVED	R.SCHMITT	12-DEC-2007
USED ON		
MATERIAL		

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	3 OF 4	M

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT



Piping covered in this note is highlighted according to the following key:

- 100 psig MAWP - pressure tested @ 111.5 psig (126.5 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig
- 60 psig MAWP - pressure tested @ 66 psig
- 3 psig MAWP - pressure tested @ 3.75 psig
- 25 psig MAWP - pressure tested @ 29 psig (44 psid for VJ portions)
- 100 psig MAWP - pressure tested @ 110 psig (482 deg. F piping)

ORIGINATOR	R.SCHMITT	26-JUN-2007
DRAWN	J.CATALANELLO	07-DEC-2007
CHECKED	R.SCHMITT	12-DEC-2007
APPROVED	R.SCHMITT	12-DEC-2007

UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL

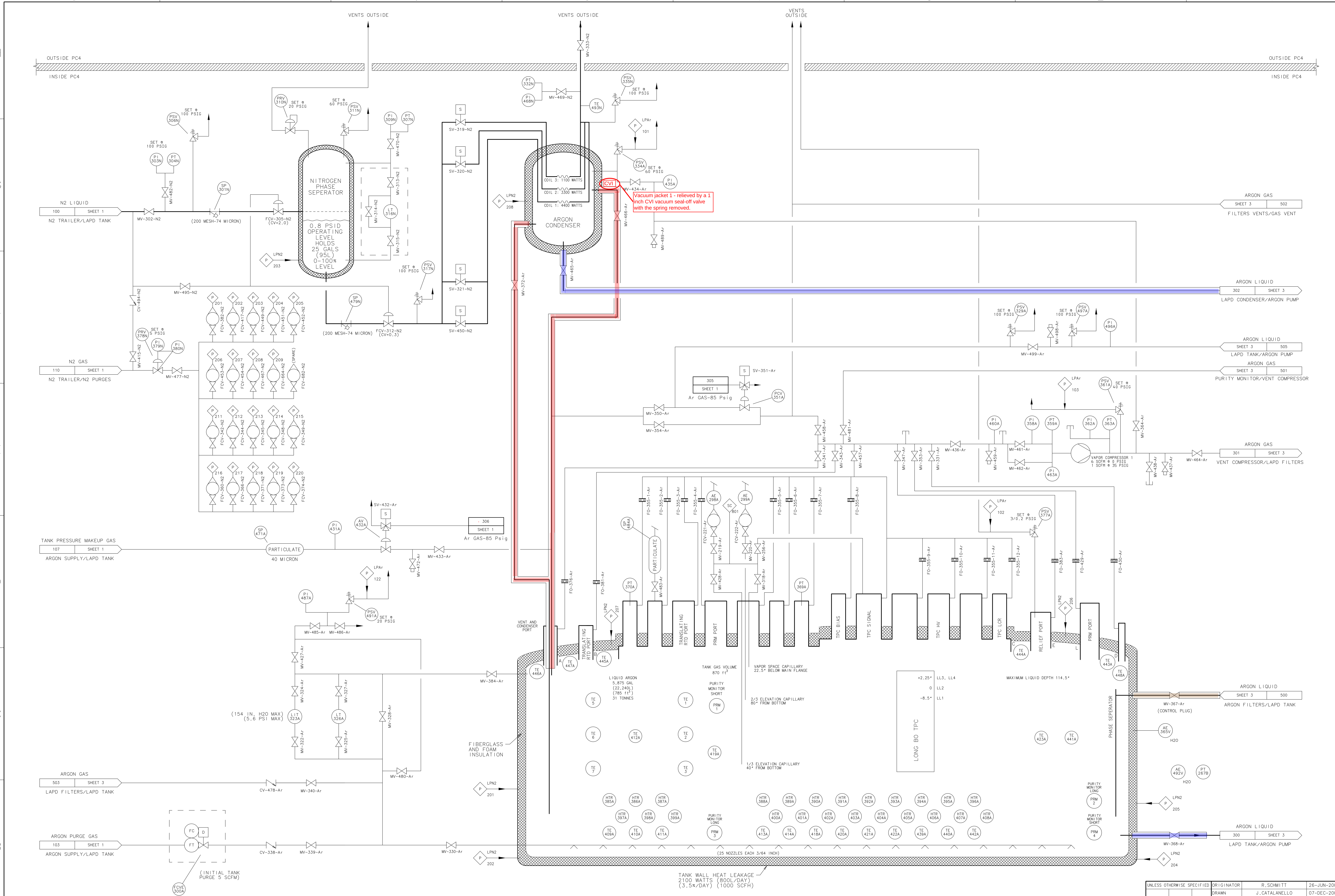
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	4 OF 4	M

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

Created: 08:12:24 on 18-10-12 (D-M-Y) By: catalan State: 1-INITIAL



Vacuum jacket 1 - relief provided by a 1 inch CVI vacuum seal-off valve with the spring removed.

Vacuum jacket 2 - relief provided by a 1 inch CVI vacuum seal-off valve with the spring removed.

Vacuum jacket 3 - relief provided by three 1 inch CVI vacuum seal-off valves.

Vacuum jacket 4 - relief provided by a parallel plate relief valve.

Vacuum jacket 5 - relief provided by a 1 inch CVI vacuum seal-off valve.

Vacuum jacket 6 - relief provided by a parallel plate relief valve.

Vacuum jacket 7 - relief provided by a parallel plate relief valve.

Vacuum jacket 8 - relief provided by a 1 inch CVI vacuum seal-off valve.

UNLESS OTHERWISE SPECIFIED	ORIGINATOR	R.SCHMITT	26-JUN-2007
	DRAWN	J.CATALANELLO	07-DEC-2007
	CHECKED	R.SCHMITT	12-DEC-2007
	APPROVED	R.SCHMITT	12-DEC-2007

1. BREAK ALL SHARP EDGES
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON

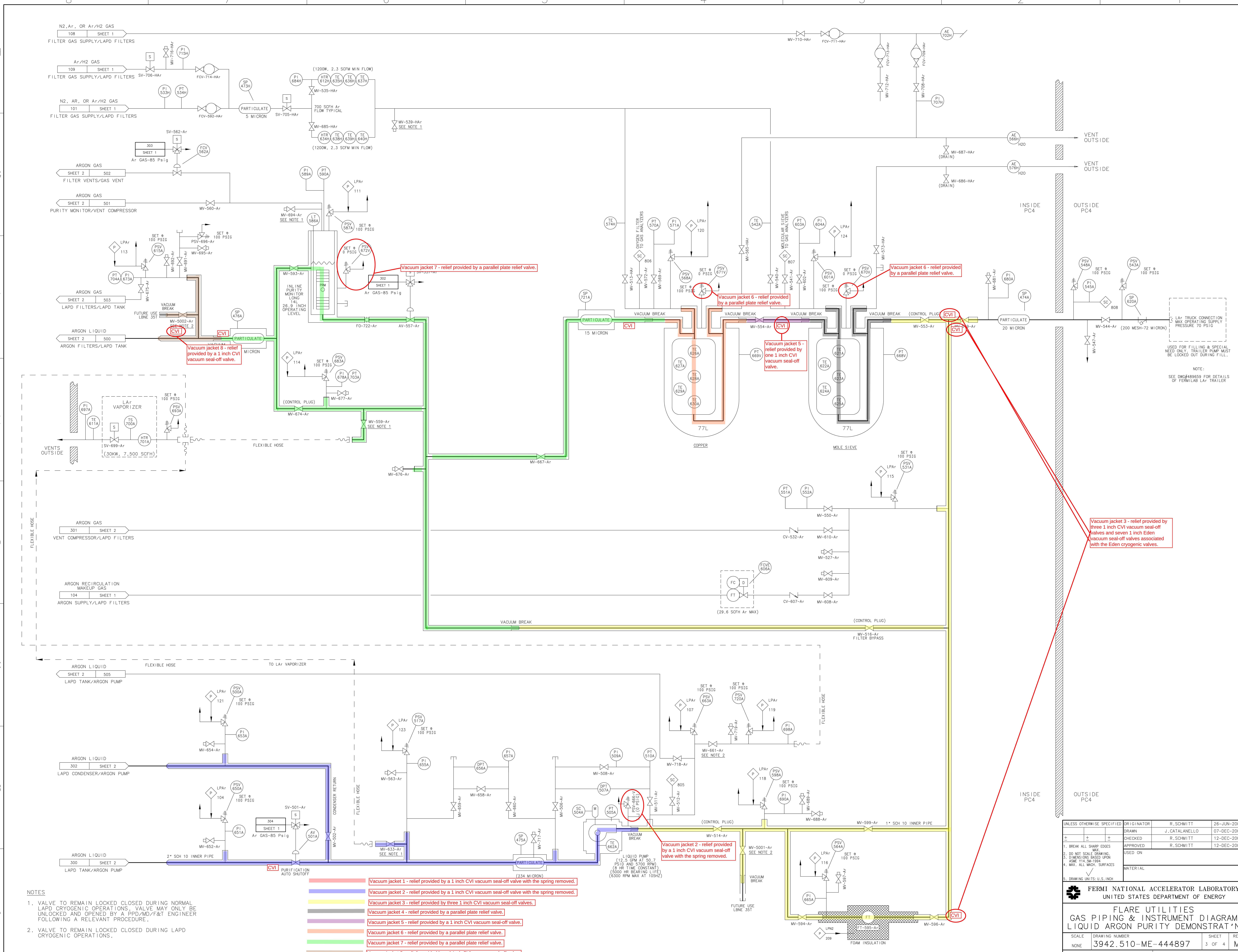
MATERIAL

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	2 OF 4	M

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT



Created: 08:12:17 on 18-10-12 (D-M-Y) By: catalan State: 1-INITIAL

Appendix B
Mechanical Drawings

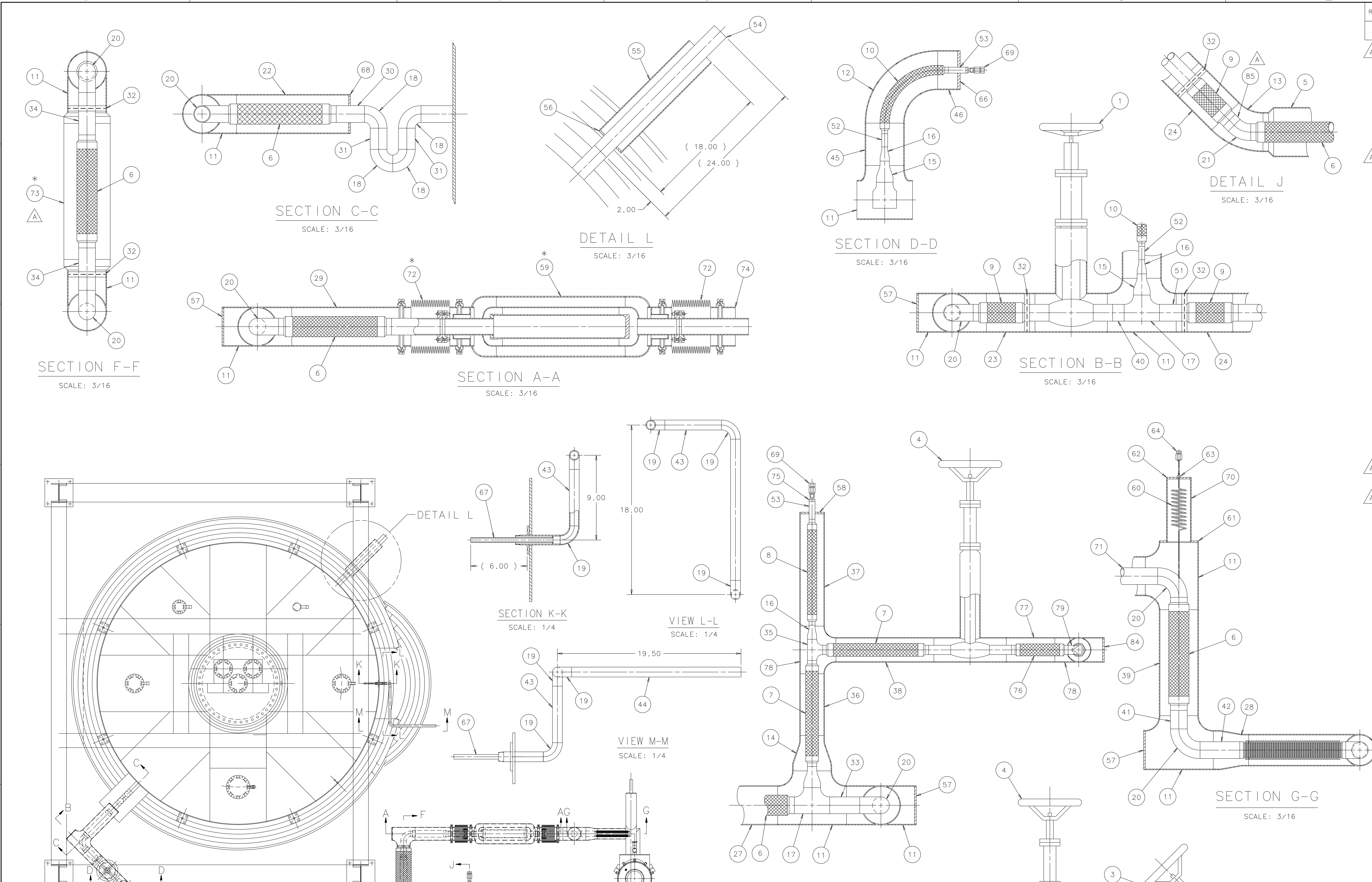
ME-486146 – drawing has been annotated to document changes

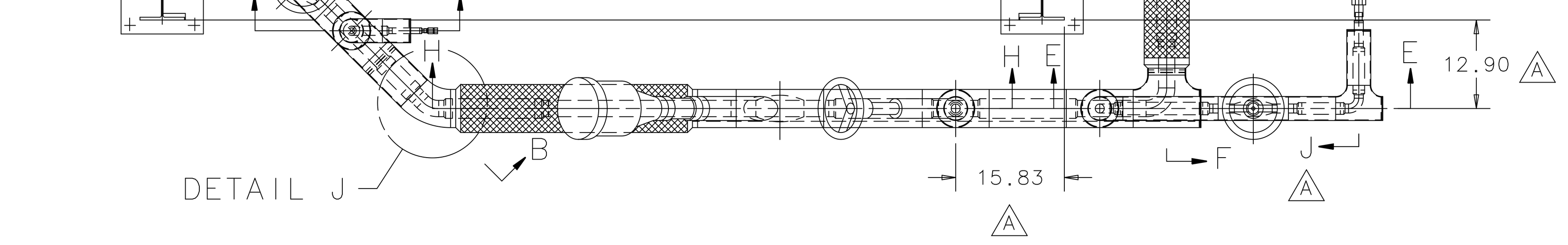
ME-489656 – new drawing

ME-486264 - drawing has been annotated to document changes

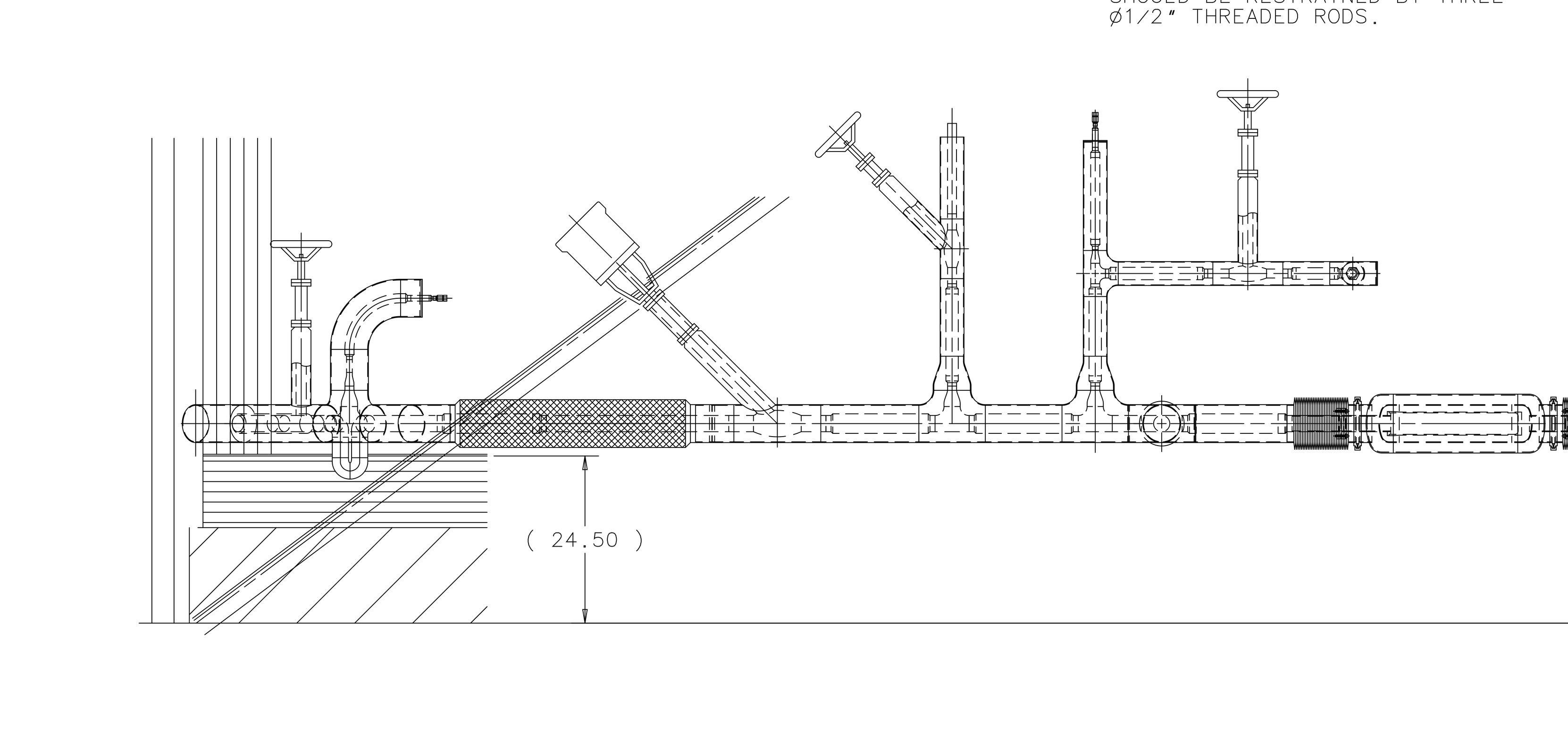
ME-486428 - drawing has been annotated to document changes

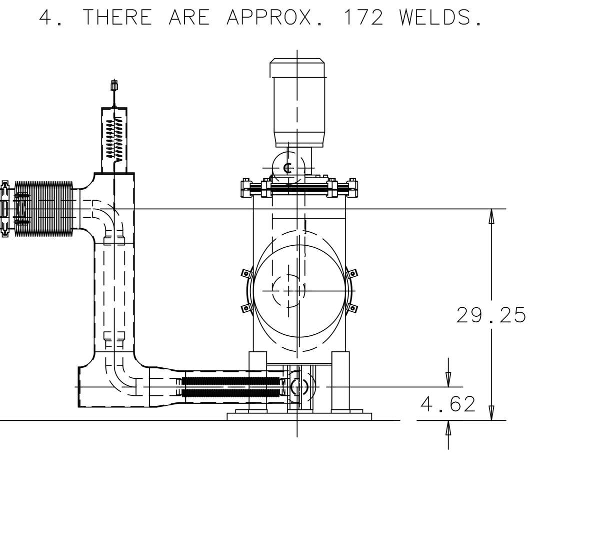
ME-489654 - new drawing





SPECIAL NOTE: * THE 5" FLEX HOSE (ITEMS 5 & 72) SHOULD BE RESTRAINED BY THREE Ø1/2" THREADED RODS.

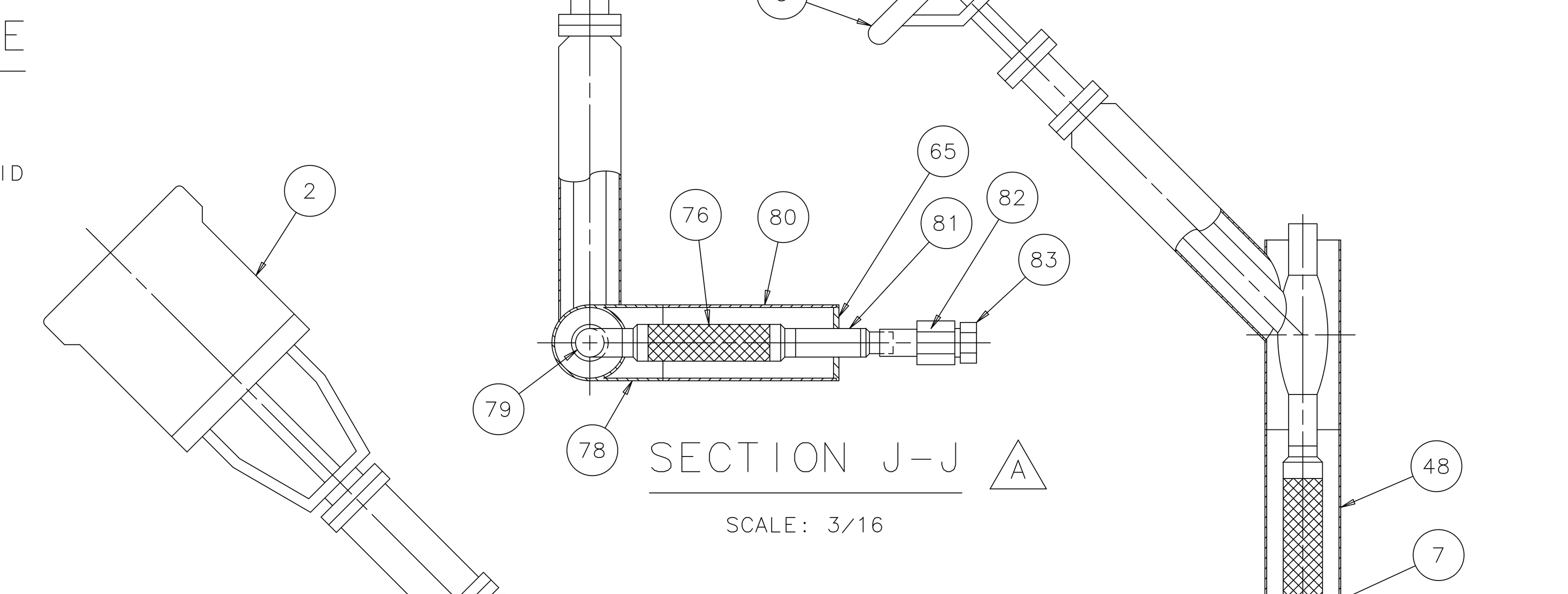


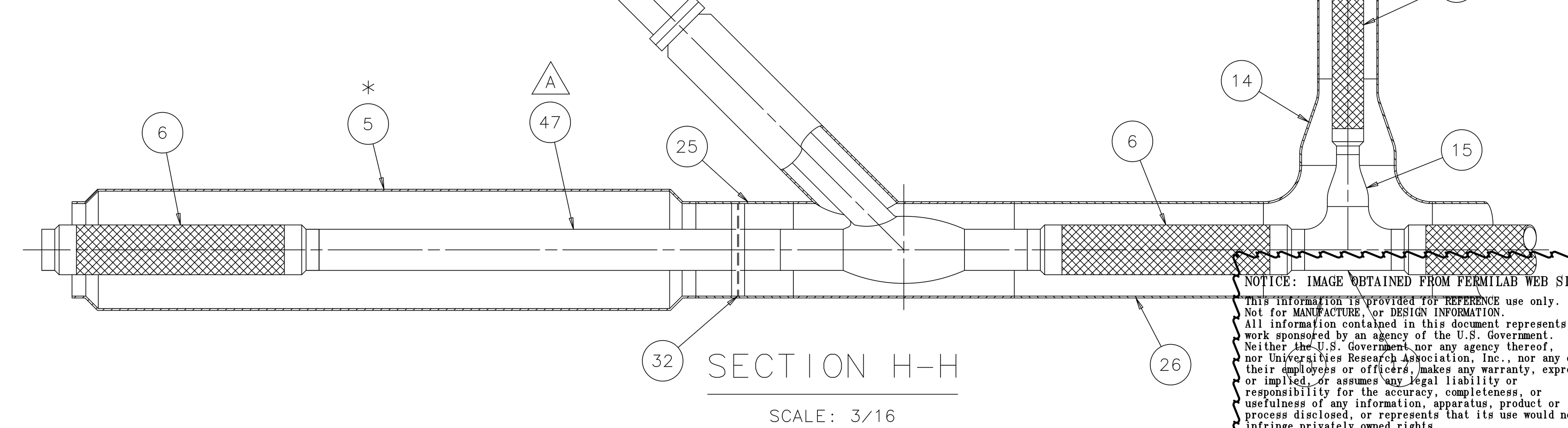


NOTE:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. THERE ARE APPROX. 172 WELDS.





REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	ADDED ITEMS 76 THRU 85. ADDED SECTION J-J. REVISED ITEM 73. ADDED DIMENSIONS 12.90 & 15.83. REMOVED ITEMS 49 & 50. REVISED LENGTH OF ITEM 47, WAS 26.75 NOW 26.62. ADDED NOTES.	B.CYKO / T.TOPE	18 AUG 2010 / 18 AUG 2010

PARTS LIST

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
85	COML	PIPE, 2" SCH.10 X 1.00 LG., S.S. 304	1
84	MD-466930-10	ADAPTER, 3" SCH. 10	1
83	COML	VCR CONNECTOR, 1" O.D. TUBE, S.S. 304	1
82	FURNISHED	ADAPTER,1"IPS PIPE X 1" O.D. TUBE	1
81	COML	PIPE, 1" SCH.10 X 3.00 LG., S.S. 304	1
80	COML	PIPE, 3" SCH.10 X 8.00 LG., S.S. 304	1
79	COML	ELBOW, 90°, LONG RADIUS, 1" SCH. 10, S.S. 304	1
78	COML	TEE, STRAIGHT, 3" SCH. 10. S.S. 304	2
77	COML	PIPE, 3" SCH.10 X 6.88 LG., S.S. 304	1
76	FURNISHED	FLEX HOSE, 1" IPS PIPE ENDS X 8.00 LG.	1
75	MB-486152	ADAPTER, 1/2" PIPE X 1/2" TUBE	1
74	COML	PIPE, 5" SCH.10 X 1.81 LG., S.S. 304	1
73	FURNISHED	FLEX HOSE, 5" IPS PIPE ENDS X 24.25 LG.	1
72	MB-466934	WELDED BELLOWS	2
71	COML	PIPE, 2" SCH.10 X 9.38 LG., S.S. 304	1
70	COML	PIPE, 3" SCH.10 X 9.00 LG., S.S. 304	1
69	COML	VCR CONNECTOR, 1/4" O.D. TUBE, S.S.304	2
68	MD-466930-8	ADAPTER, 2" X 5" SCH. 10 PIPE	1
67	COML	TUBING, 1/2" O.D. X .049 WALL X 8.75 LG.	1
66	MD-466930-7	ADAPTER, 1/2" X 5" SCH. 10 PIPE	1
65	MD-466930-6	ADAPTER, 1" X 3" SCH. 10 PIPE	1
64	COML	VCR CONNECTOR, 1/4" O.D. TUBE, S.S.304	1
63	MD-466930-9	ADAPTER, 1/4" O.D. TUBE	1
62	MD-466930-5	ADAPTER, 5" SCH. 10 PIPE	1
61	MD-466930-4	ADAPTER, 3" X 5" SCH. 10 PIPE	1
60	MC-466933	1/8" O.D. CAPILLARY TUBE	1
59	MD-466888	FILTER ASSEMBLY	1
58	MD-466930-3	ADAPTER, 1/2" X 3" SCH. 10 PIPE	1
57	MD-466930-2	ADAPTER, 5" SCH. 10 PIPE	4
56	MD-466930-1	ADAPTER, 2" X 4" SCH. 10 PIPE	1
55	COML	PIPE, 4" SCH.10 X 18.00 LG., S.S. 304	1
54	COML	PIPE, 2" SCH.10 X 24.00 LG., S.S. 304	1
53	COML	PIPE, 1/2" SCH.10 X 2.50 LG., S.S. 304	2
52	COML	PIPE, 1/2" SCH.10 X 1.88 LG., S.S. 304	2
51	COML	PIPE, 2" SCH.10 X 3.16 LG., S.S. 304	1
50		DELETED	
49		DELETED	
48	COML	PIPE, 3" SCH.10 X 11.38 LG., S.S. 304	1
47	COML	PIPE, 2" SCH.10 X 26.62 LG., S.S. 304	1
46	COML	PIPE, 5" SCH.10 X 3.00 LG., S.S. 304	1
45	COML	PIPE, 5" SCH.10 X 6.00 LG., S.S. 304	1
44	COML	PIPE, 3/4" SCH.10 X 18.00 LG., S.S. 304	1
43	COML	PIPE, 3/4" SCH.10 X 6.00 LG., S.S. 304	2
42	COML	PIPE, 2" SCH.10 X 5.63 LG., S.S. 304	1
41	COML	PIPE, 2" SCH.10 X 2.63 LG., S.S. 304	1
40	COML	PIPE, 2" SCH.10 X 1.63 LG., S.S. 304	1
39	COML	PIPE, 5" SCH.10 X 15.00 LG., S.S. 304	1
38	COML	PIPE, 3" SCH.10 X 13.88 LG., S.S. 304	1
37	COML	PIPE, 3" SCH.10 X 16.00 LG., S.S. 304	1
36	COML	PIPE, 3" SCH.10 X 8.75 LG., S.S. 304	1
35	COML	TEE, STRAIGHT, 1" SCH. 40, S.S. 304	1
34	COML	PIPE, 2" SCH.10 X 6.00 LG., S.S. 304	2
33	COML	PIPE, 2" SCH.10 X 4.25 LG., S.S. 304	1
32	MB-466935	CRYO LINE SPACER	5
31	COML	PIPE, 2" SCH.10 X 3.00 LG., S.S. 304	2
30	COML	PIPE, 2" SCH.10 X 4.00 LG., S.S. 304	1
29	COML	PIPE, 5" SCH.10 X 15.18 LG., S.S. 304	1
28	COML	REDUCER, CONCENTRIC, 5" X 4" SCH.10, S.S. 304	1
27	COML	PIPE, 5" SCH.10 X 11.25 LG., S.S. 304	1
26	COML	PIPE, 5" SCH.10 X 14.38 LG., S.S. 304	1
25	COML	PIPE, 5" SCH.10 X 5.63 LG., S.S. 304	1
24	COML	PIPE, 5" SCH.10 X 8.00 LG., S.S. 304	1
23	COML	PIPE, 5" SCH.10 X 6.88 LG., S.S. 304	1
22	COML	PIPE, 5" SCH.10 X 16.00 LG., S.S. 304	1
21	COML	ELBOW, 45°, 2" SCH.10 S.S. 304	1
20	COML	ELBOW, 90°, LONG RAD.,2" SCH.10 S.S. 304	7
19	COML	ELBOW, 90°, LONG RAD.,3/4" SCH.10 S.S. 304	3
18	COML	ELBOW, 90°, SHORT RAD.,2" SCH.10 S.S. 304	4
17	COML	TEE, STRAIGHT, 2" SCH. 10, S.S. 304	3
16	COML	REDUCER, CONCENTRIC, 1" X 1/2" SCH. 10	3
15	COML	REDUCER, CONCENTRIC, 2" X 1" SCH. 10	3
14	COML	REDUCER, CONCENTRIC, 5" X 3" SCH. 10	2
13	COML	ELBOW, 45°,5"SCH.10, S.S. 304	1
12	COML	ELBOW, 90°, LONG RAD.,5" SCH.10 S.S. 304	1
11	COML	TEE, STRAIGHT, 5" SCH. 10, S.S. 304	12
10	FURNISHED	FLEX HOSE,(BENT) 1/2" SCH. 10 IPS ENDS 14.75 OAL	1
9	FURNISHED	FLEX HOSE,(SHORT) 2" SCH. 10 IPS ENDS 8" OAL	2
8	FURNISHED	FLEX HOSE, 1/2" SCH. 10 IPS ENDS 15" OAL	1
7	FURNISHED	FLEX HOSE, 1" SCH. 10 IPS ENDS 15" OAL	2
6	FURNISHED	FLEX HOSE, 2" SCH. 10 IPS ENDS 16" OAL	7
5	FURNISHED	FLEX HOSE, 5" SCH. 10 IPS ENDS 36" OAL	1
4	COML	1" GLOBE VALVE, EDEN BC-02146-	1
3	COML	1" Y PATTERN REMOTE VALVE EDEN BC-02146-8122	1
2	COML	2" Y PATTERN REMOTE VALVE EDEN BC-02146-8132	1
1	COML	2" GLOBE VALVE, EDEN BC-02146-8119	1

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	T.TOPE	06-MAY-2010
± -----	± .03	±-----	DRAWN	W.CYKO	06-MAY-2010
			CHECKED	J.RAUCH	24-MAY-2010
			APPROVED	T.TOPE	25-MAY-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS:U.S.INCH

USED ON

MATERIAL: SEE PARTS LIST ABOVE

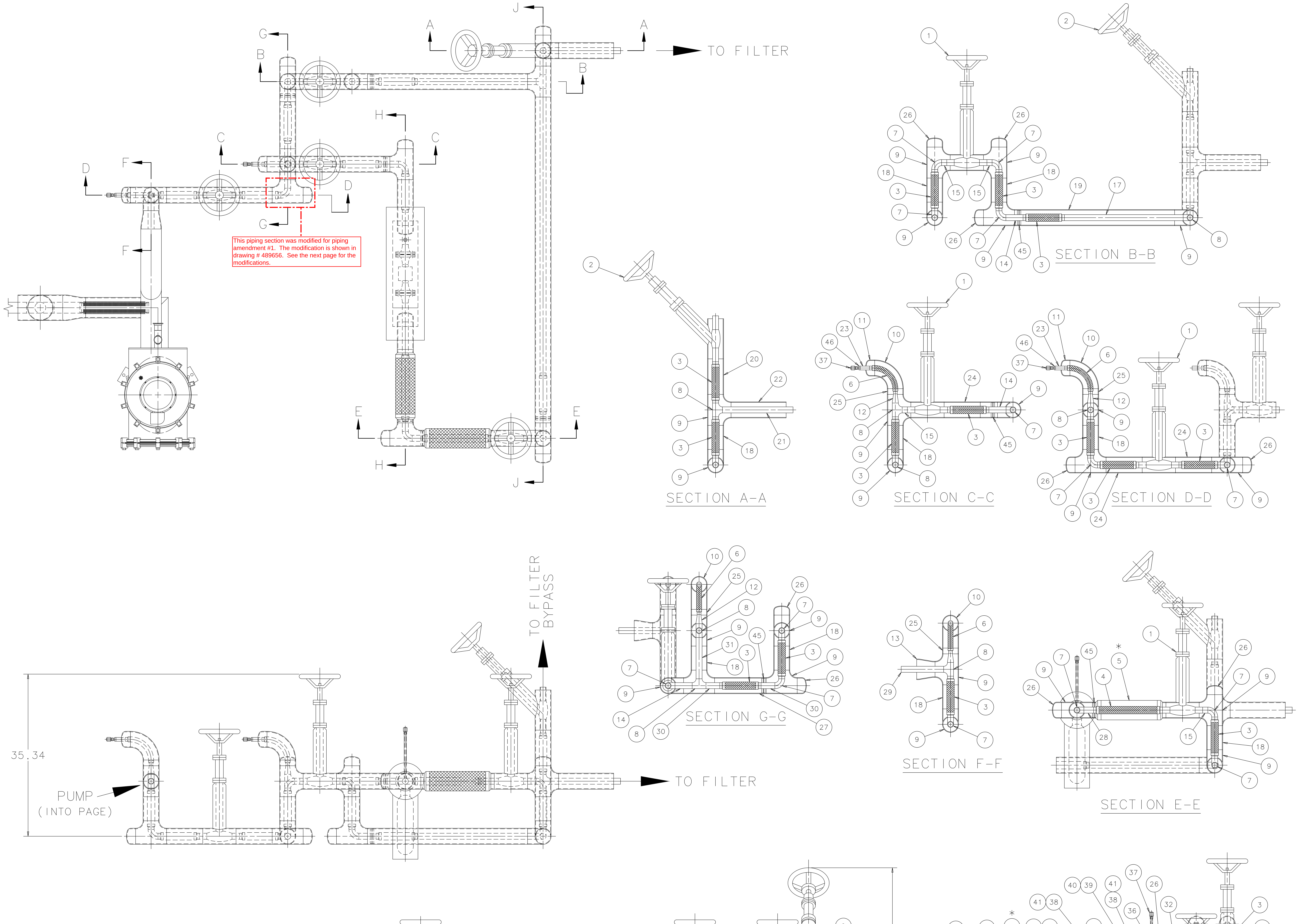
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

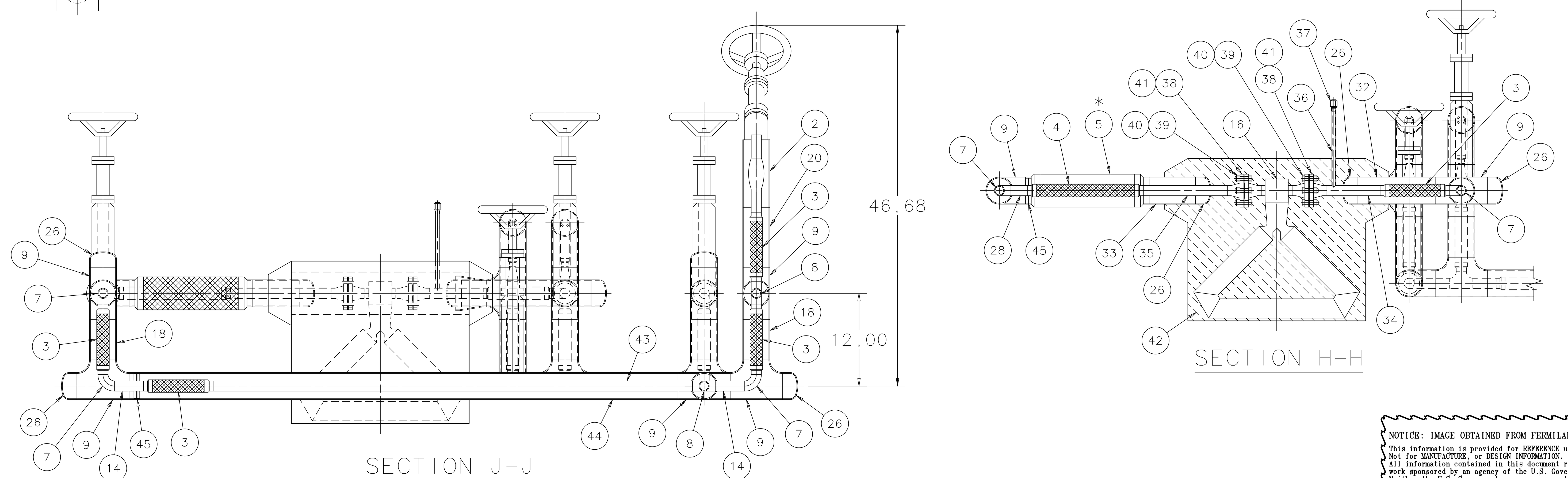
FLARE-MECHANICAL CRYOGENIC LAPD TANK CRYO PIPING PHASE 1

SCALE	DRAWING NUMBER	SHEET	REV
1:16 & NOTED	3942.320-ME-466884	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	REVISED ITEM 19 WAS 31.12 IS NOW 34.88	B.CYKO	27 OCT 2010
		T.TOPE	27 OCT 2010
B	ADDED NOTE.	B.CYKO	T.TOPE
		06 DEC 2010	06 DEC 2010





B * SPECIAL NOTE: THE 3" FLEX HOSES (ITEM 5) SHOULD BE RESTRAINED BY THREE Ø3/8 THREADED RODS.

B NOTE:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. THERE ARE APPROX. 173 WELDS.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
46	MB-486152	ADAPTER, 1/2" PIPE X 1/2" O.D. TUBE	2
45	MB-486151	CRYO SPACER, 3" X 1" PIPE	5
44	COML	PIPE, 3" SCH. 10 X 71.00 LG.	1
43	COML	PIPE, 1" SCH. 10 X 62.00 LG.	1
42	FURNISHED	FOAM INSULATION	AS REQD.
41	FURNISHED	HEX NUT, 1/2"-13 UNC	8
40	FURNISHED	HHCS, 1/2"-13 UNC X 1.75 LG.	8
39	FURNISHED	GASKET	2
38	FURNISHED	FLANGE, 1" CLASS 150, WELD NECK, R.F.	4
37	COML	VCR CONNECTOR, 1/2", M X F	3
36	COML	TUBING, 1/2" O.D. X .049 WALL X 10.00 LG.	1
35	COML	PIPE, 1" SCH. 10 X 10.88 LG.	1
34	COML	PIPE, 1" SCH. 10 X 7.00 LG.	1
33	COML	PIPE, 3" SCH. 10 X 6.00 LG.	1
32	COML	PIPE, 3" SCH. 10 X 10.00 LG.	1
31	COML	PIPE, 1" SCH. 10 X 9.00 LG.	1
30	COML	PIPE, 1" SCH. 10 X 3.00 LG.	2
29	COML	PIPE, 1" SCH. 10 X 9.25 LG.	1
28	COML	PIPE, 1" SCH. 10 X 2.12 LG.	1
27	COML	PIPE, 3" SCH. 10 X 11.25 LG.	1
26	COML	PIPE CAP, 3" SCH. 10	11
25	COML	PIPE, 3" SCH. 10 X 1.25 LG.	4
24	COML	PIPE, 3" SCH. 10 X 7.88 LG.	1
23	COML	PIPE, 1/2" SCH. 10 X 2.00 LG.	2
22	COML	PIPE, 3" SCH. 10 X 12.00 LG.	1
21	COML	PIPE, 1" SCH. 10 X 15.38 LG.	1
20	COML	PIPE, 3" SCH. 10 X 7.75 LG.	2
19	COML	PIPE, 3" SCH. 10 X 34.88 LG.	1
18	COML	PIPE, 3" SCH. 10 X 5.25 LG.	11
17	COML	PIPE, 1" SCH. 10 X 25.88 LG.	1
16	FURNISHED	FLOW METER, MICRO MOTION INC.	1
15	COML	PIPE, 1" SCH. 10 X 1.12 LG.	4
14	COML	PIPE, 1" SCH. 10 X 3.75 LG.	5
13	COML	REDUCER, CONCENTRIC, 4" X 3" SCH. 10	1
12	COML	REDUCER, CONCENTRIC, 1" X 1/2" SCH. 10	2
11	MB-486084-3	PIPE CAP, 3" SCH. 10 X 1" IPS	2
10	COML	ELBOW, 90°, LONG RADIUS, 3" SCH. 10	2
9	COML	TEE, STRAIGHT, 3" SCH. 10	14
8	COML	TEE, STRAIGHT, 1" SCH. 10	4
7	COML	ELBOW, 90°, LONG RADIUS, 1" SCH. 10	8
6	FURNISHED	FLEX HOSE, 1/2" IPS ENDS X 9.25 OAL	2
5	FURNISHED	FLEX HOSE, 3" IPS ENDS X 16.00 OAL	2
4	FURNISHED	FLEX HOSE, 1" IPS ENDS X 15.00 OAL	2
3	FURNISHED	FLEX HOSE, 1" IPS ENDS X 9.00 OAL	15
2	FURNISHED	1" IPS Y PATTERN GLOBE VALVE, EDEN	1
1	FURNISHED	1" IPS GLOBE VALVE, EDEN	4

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	T.TOPE	05-AUG-2010
± .06	± -----	±-----	DRAWN	W.CYKO	05-AUG-2010
			CHECKED	T.TOPE	17-AUG-2010
			APPROVED	T.TOPE	17-AUG-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

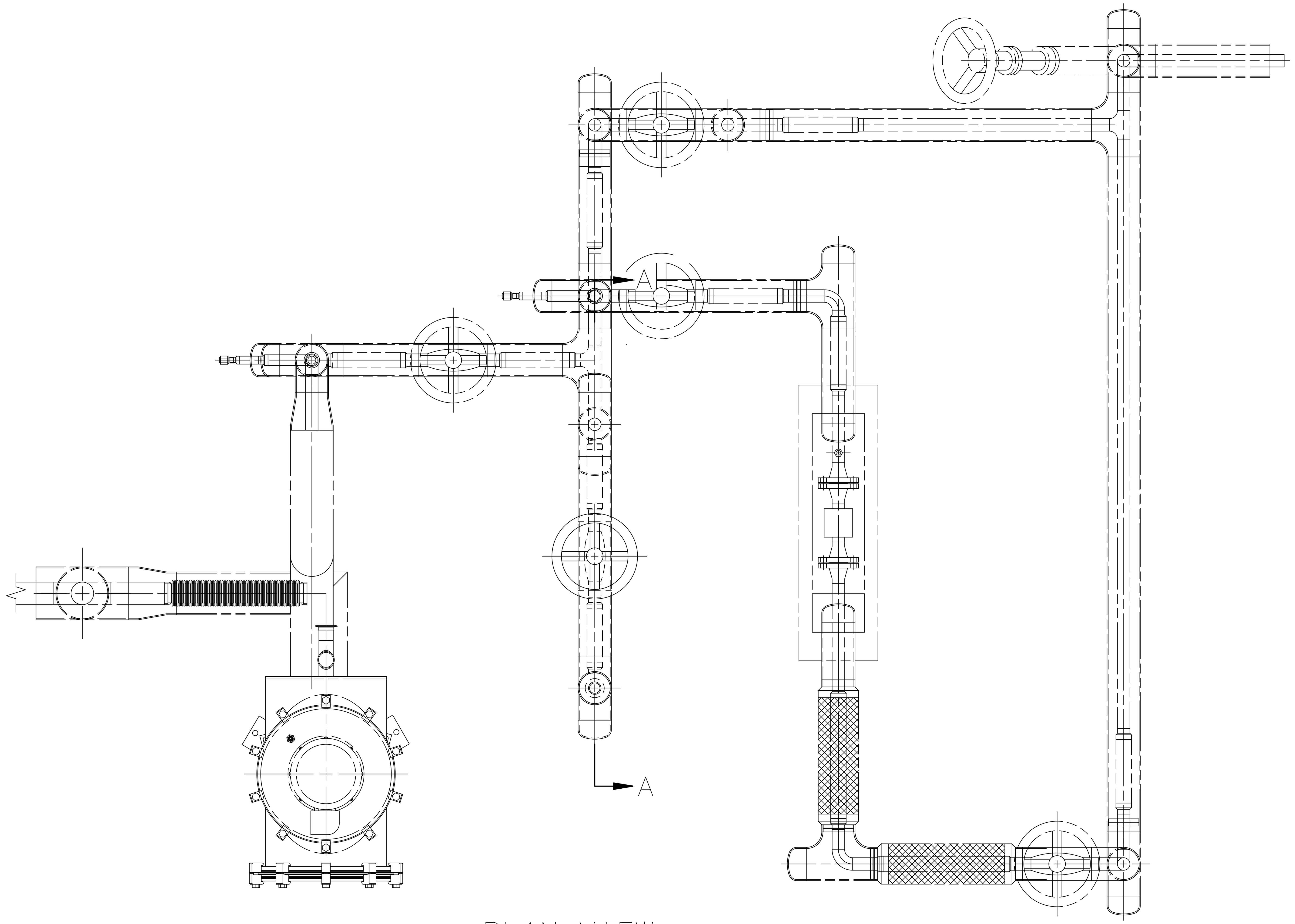
MATERIAL SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

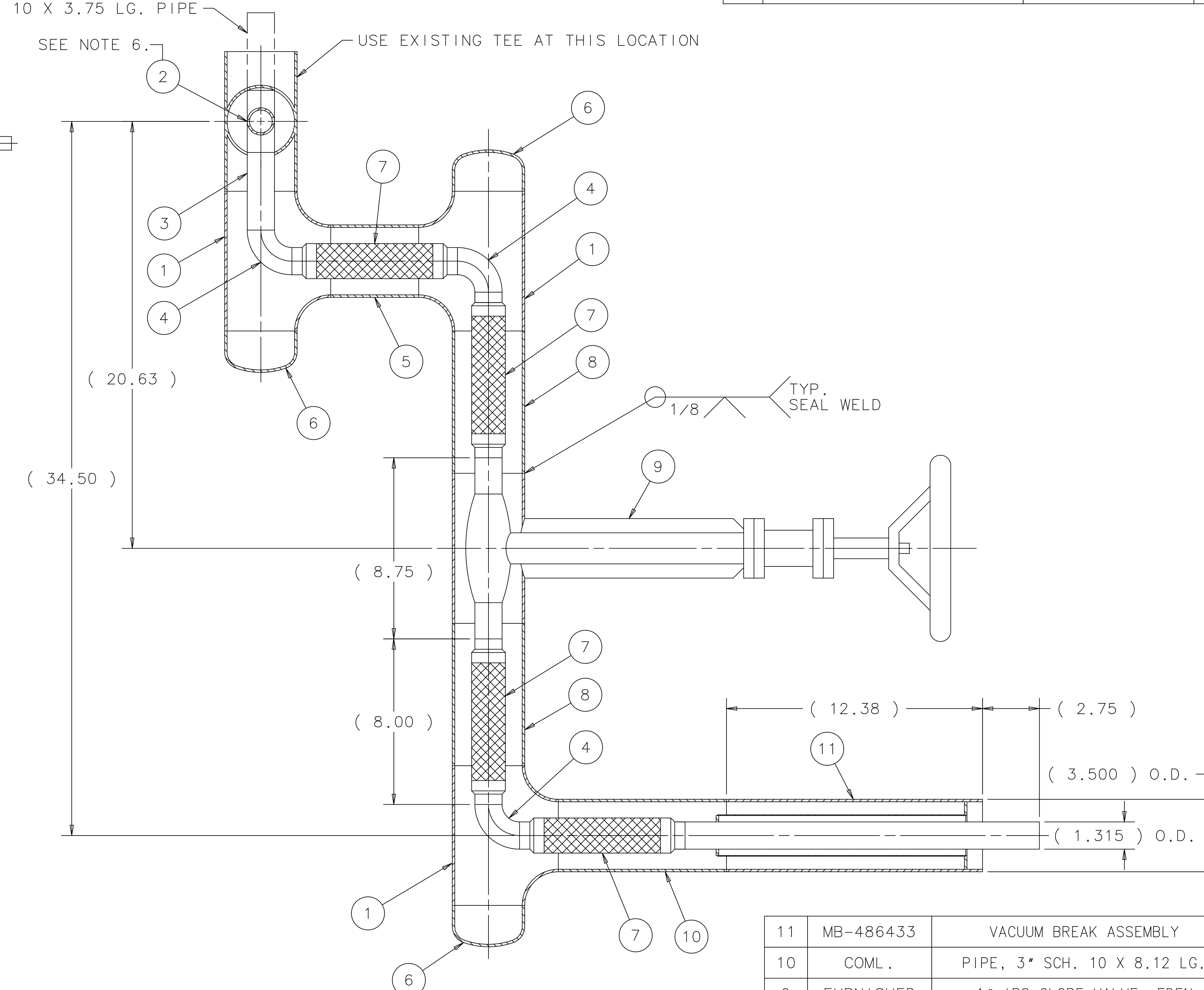
FLARE-MECHANICAL CRYOGENIC LAPD TANK CRYO PIPING PHASE 3

SCALE	DRAWING NUMBER	SHEET	REV
1:8	3942.320-ME-486146	1 OF 1	B

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT



PLAN VIEW FROM DRAWING ME-486146



SECTION A-A

SCALE: 1:4

NOTES:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. THERE ARE APPROX. 26 WELDS.
5. UNLESS OTHERWISE SPECIFIED, ALL MATERIAL TO BE STAINLESS STEEL TYPE 304.
6. THIS ITEM REPLACES 1" SCH. 10, 90° LONG R., ELBOW SHOWN ON DRAWING ME-486146 PLAN VIEW ITEM 7.

REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE

PARTS LIST

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
11	MB-486433	VACUUM BREAK ASSEMBLY	1
10	COML.	PIPE, 3" SCH. 10 X 8.12 LG.	1
9	FURNISHED	1" IPS GLOBE VALVE, EDEN	1
8	COML.	PIPE, 3" SCH. 10 X 6.88 LG.	2
7	FURNISHED	FLEX HOSE, 1" IPS ENDS X 8.00 OAL	4
6	COML.	PIPE CAP, 3" SCH. 10	3
5	COML.	PIPE, 3" SCH. 10 X 4.25 LG.	1
4	COML.	ELBOW, 90°, LONG R., 1" SCH. 10	3
3	COML.	PIPE, 1" SCH. 10 X 3.75 LG.	2
SEE NOTE 6. 2	COML.	TEE, STRAIGHT, 1" SCH. 10	1
1	COML.	TEE, STRAIGHT, 3" SCH. 10	3

UNLESS OTHERWISE SPECIFIED: .XX ± .06; .XXX ± - -; ANGLES ± - -

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M 1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: INCHES

ORIGINATOR	T.TOPE	18-APR-2012
DRAWN	W.CYKO	18-APR-2012
CHECKED	J.RAUCH	20-APR-2012
APPROVED	T.TOPE	20-APR-2012

USED ON

MATERIAL: SEE PARTS LIST ABOVE

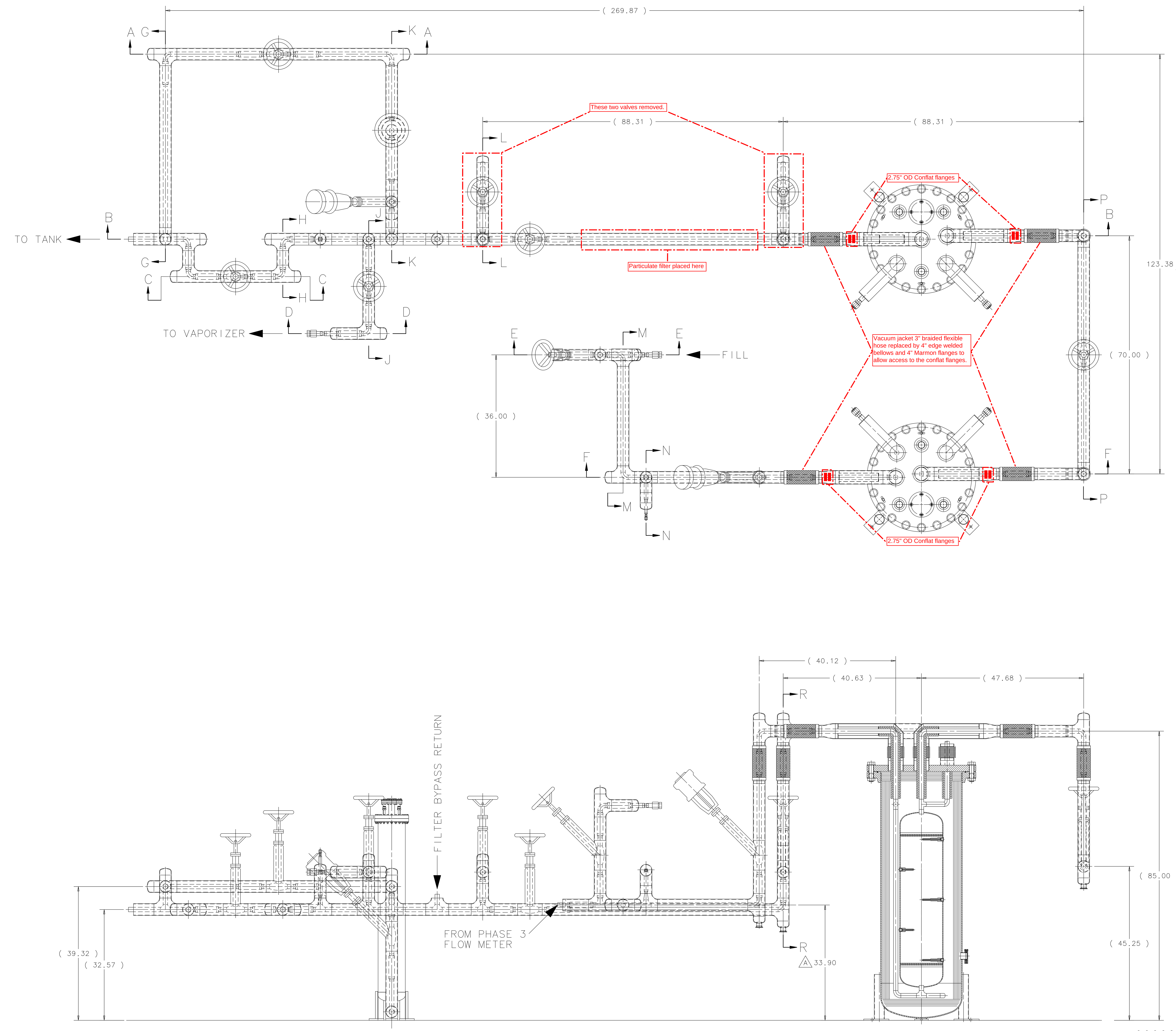
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE-MECHANICAL
CRYOGENIC
LAPD TIE-IN TO LBNE 35T PIPING B

SCALE	DRAWING NUMBER	SHEET	REV
1:8 & AS NOTED	3942.320-MD-489656	1 OF 1	

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	ADDED SECTION R-R, 123.38 WAS 124.12, 33.90 WAS 15.88	B.CYKO / T.TOPE	12-NOV-2010 / 12-NOV-2010



UNLESS OTHERWISE SPECIFIED			ORIGINATOR	T.TOPE	29-SEP-2010
.XX	.XXX	ANGLES	DRAWN	W.CYKO	29-SEP-2010
± .03	± -----	±-----	CHECKED	T.TOPE	29-OCT-2010
			APPROVED	T.TOPE	29-OCT-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL: SEE PARTS LIST ABOVE

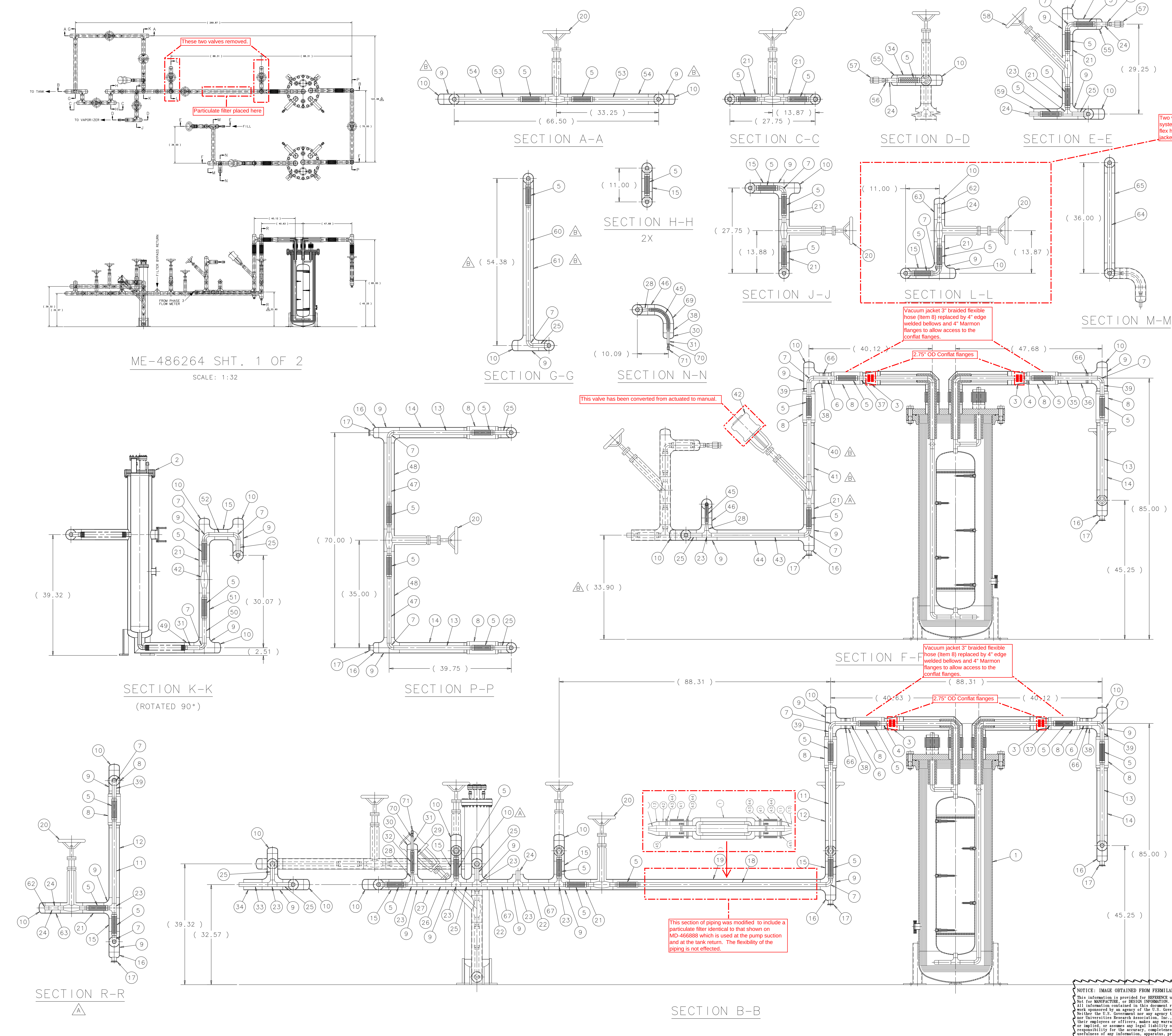
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE-MECHANICAL CRYOGENIC LAPD TANK CRYO PIPING PHASE 4

SCALE	DRAWING NUMBER	SHEET	REV
1:8 & AS NOTED	3942.330-ME-486264	1 OF 2	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	CHANGED QTY. OF ITEM 31 TO "2", ITEM 10 TO "24" & ITEM 15 TO "8". ADDED ITEM 72. DELETED ITEM 68. CHANGED ITEM 6 TO 21 IN SECTION F-F. ADDED SECTION R-R.	B.CYKO	11-03-2010
		T.TOPE	11-03-2010



	ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
A	72	COML	PIPE, 1" SCH. 10 X 4.00 LG.	1
	71	COML	VCR CONNECTOR, 1/2" O.D. TUBE	2
	70	MB-486152	ADAPTER, 1/2" PIPE X 1/2" O.D. TUBE	2
	69	COML	ELBOW, 90°, LONG R, 3" SCH. 10	1
A	68		DELETED	
	67	COML	PIPE, 1" SCH. 10 X 10.38 LG.	2
	66	MB-486151	SPACER, 3" SCH. 10 X 1" IPS	4
	65	COML	PIPE, 3" SCH. 10 X 29.25 LG.	1
	64	COML	PIPE, 1" SCH. 10 X 33.00 LG.	1
	63	COML	PIPE, 3" SCH. 10 X 5.00 LG.	1
	62	COML	PIPE CAP 1" SCH. 10	1
A	61	COML	PIPE, 3" SCH. 10 X 47.63 LG.	1
	60	COML	PIPE, 1" SCH. 10 X 43.38 LG.	1
	59	COML	PIPE, 3" SCH. 10 X 7.63 LG.	1
	58	COML	1" Y-PATTERN MANUAL VALVE, EDEN P/N BC-02146-8122	1
	57	COML	VCR CONNECTOR, 1" O.D. TUBE	2
	56	MB-486345	ADAPTER, 1" IPS X 1.00 O.D. TUBE	2
	55	COML	PIPE CAP, 3" SCH. 10 X 1" IPS	2
	54	COML	PIPE, 3" SCH. 10 X 26.25 LG.	2
	53	COML	PIPE, 1" SCH. 10 X 19.38 LG.	2
	52	COML	PIPE, 1" SCH. 10 X 8.00 LG.	1
	51	COML	PIPE, 3" SCH. 10 X 14.44 LG.	1
	50	COML	PIPE, 1" SCH. 10 X 7.56 LG.	1
	49	COML	PIPE, 3" SCH. 10 X 3.13 LG.	1
	48	COML	PIPE, 3" SCH. 10 X 28.00 LG.	2
	47	COML	PIPE, 1" SCH. 10 X 21.13 LG.	2
	46	COML	PIPE, 3" SCH. 10 X 2.25 LG.	1
	45	FURNISHED	FLEX HOSE, 1/2" IPS ENDS X 12.00 OAL	1
	44	COML	PIPE, 3" SCH. 10 X 26.50 LG.	1
	43	COML	PIPE, 1" SCH. 10 X 30.25 LG.	1
	42	COML	1" Y-PATTERN REMOTE VALVE, EDEN P/N BC-02146-8129	2
B	41	COML	PIPE, 3" SCH. 10 X 16.72 LG.	1
	40	COML	PIPE, 1" SCH. 10 X 17.97 LG.	1
	39	COML	PIPE, 1" SCH. 10 X 3.88 LG.	3
	38	COML	PIPE, 3" SCH. 10 X 3.00 LG.	4
	37	COML	PIPE, 1" SCH. 10 X 1.25 LG.	1
	36	COML	PIPE, 3" SCH. 10 X 10.06 LG.	1
	35	COML	PIPE, 1" SCH. 10 X 13.94 LG.	1
	34	COML	PIPE, 3" SCH. 10 X 6.00 LG.	3
	33	COML	PIPE, 1" SCH. 10 X 9.38 LG.	1
	32	FURNISHED	FLEX HOSE, 1/2" IPS ENDS X 8.00 OAL	1
B	31	COML	PIPE, 1/2" SCH. 10 X 4.00 LG.	2
	30	MB-486084-5	PIPE CAP, 3" SCH. 10 X 1/2" IPS	2
	29	COML	PIPE, 3" SCH. 10 X 8.00 LG.	1
	28	COML	REDUCER, CONCENTRIC, 1" X 1/2" SCH. 10	2
	27	COML	PIPE, 3" SCH. 10 X 7.50 LG.	1
	26	COML	PIPE, 1" SCH. 10 X 11.25 LG.	1
	25	COML	PIPE, 1" SCH. 10 X 3.75 LG.	10
	24	COML	PIPE, 1" SCH. 10 X 3.00 LG.	4
	23	COML	TEE, STRAIGHT, 1" SCH. 10	7
	22	COML	PIPE, 3" SCH. 10 X 6.63 LG.	2
	21	COML	PIPE, 3" SCH. 10 X 6.88 LG.	9
	20	COML	1" GLOBE VALVE, EDEN P/N BC-02146-8101	8
	19	COML	PIPE, 3" SCH. 10 X 67.44 LG.	1
	18	COML	PIPE, 1" SCH. 10 X 60.56 LG.	1
	17	COML	HALF NIPPLE, NW40, 1.50 O.D. X 1.58 LG.	4
	16	MB-486084-4	PIPE CAP, 3" SCH. 10 X 1.50 O.D. TUBE	4
A	15	COML	PIPE, 3" SCH. 10 X 4.25 LG.	8
	14	COML	PIPE, 3" SCH. 10 X 21.00 LG.	2
	13	COML	PIPE, 1" SCH. 10 X 24.88 LG.	2
	12	COML	PIPE, 3" SCH. 10 X 22.68 LG.	1
	11	COML	PIPE, 1" SCH. 10 X 26.56 LG.	1
A	10	COML	PIPE CAP, 3" SCH. 10	24
	9	COML	TEE, STRAIGHT, 3" SCH. 10	23
	8	FURNISHED	FLEX HOSE, 3" IPS ENDS X 12.00 OAL	10
	7	COML	ELBOW, 90°, LONG R, 1" SCH. 10	15
	6	COML	PIPE, 1" SCH. 10 X 6.88 LG.	4
	5	FURNISHED	FLEX HOSE, 1" IPS ENDS X 8.00 OAL	37
	4	COML	PIPE, 1" SCH. 10 X 1.75 LG.	2
	3	COML	REDUCER, CONCENTRIC, 4 X 3 SCH. 10	4
	2	MD-466995	PURITY MONITOR VESSEL	1
	1	ME-466500	PURIFIER VESSEL	2

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	T.TOPE	11-OCT-2010
± .03	± -----	±-----	DRAWN	W.CYKO	11-OCT-2010
			CHECKED	T.TOPE	29-OCT-2010
			APPROVED	T.TOPE	29-OCT-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE
ALL MAT'L S.S. 304 UNLESS OTHERWISE SPECIFIED

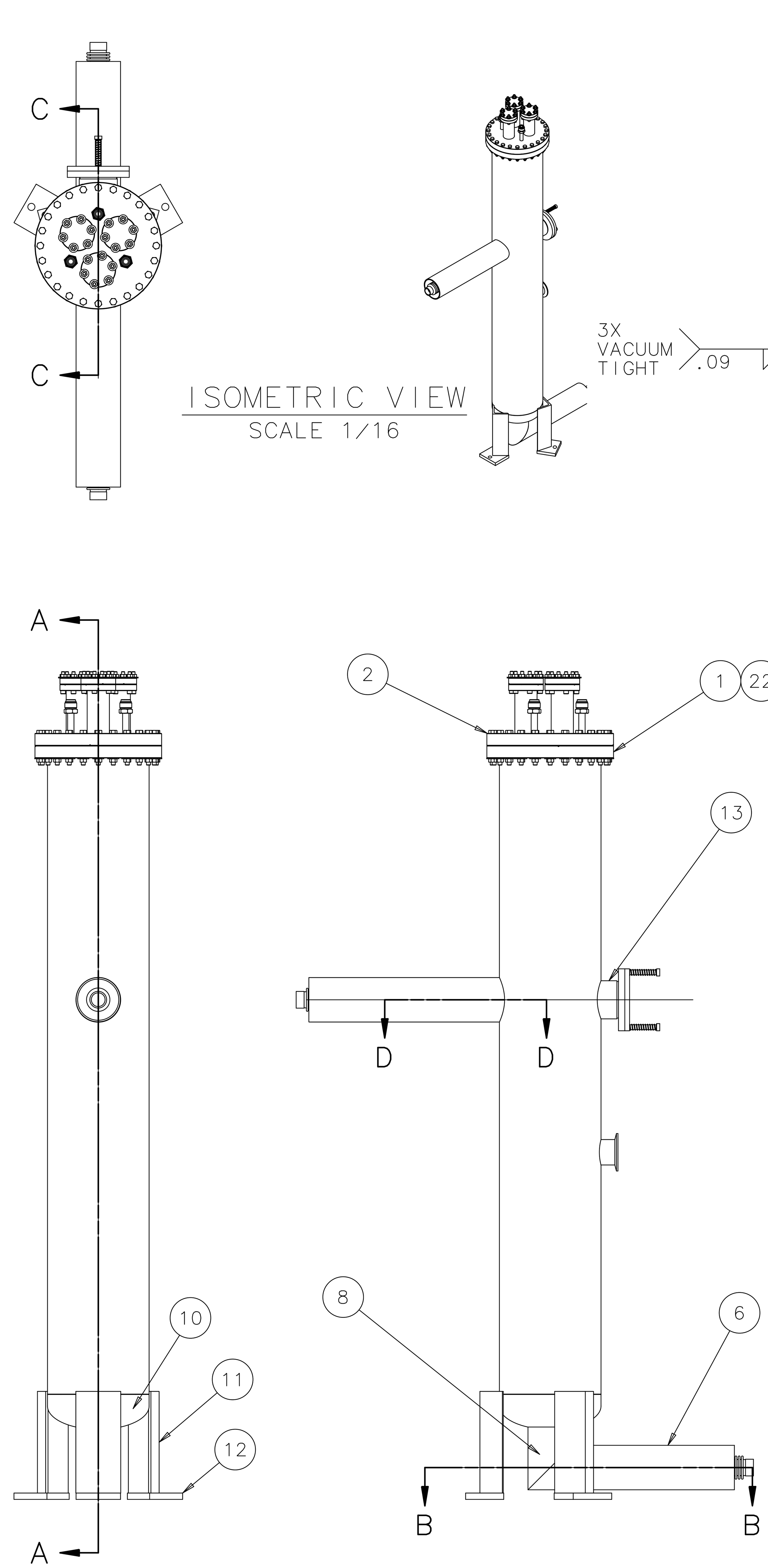
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

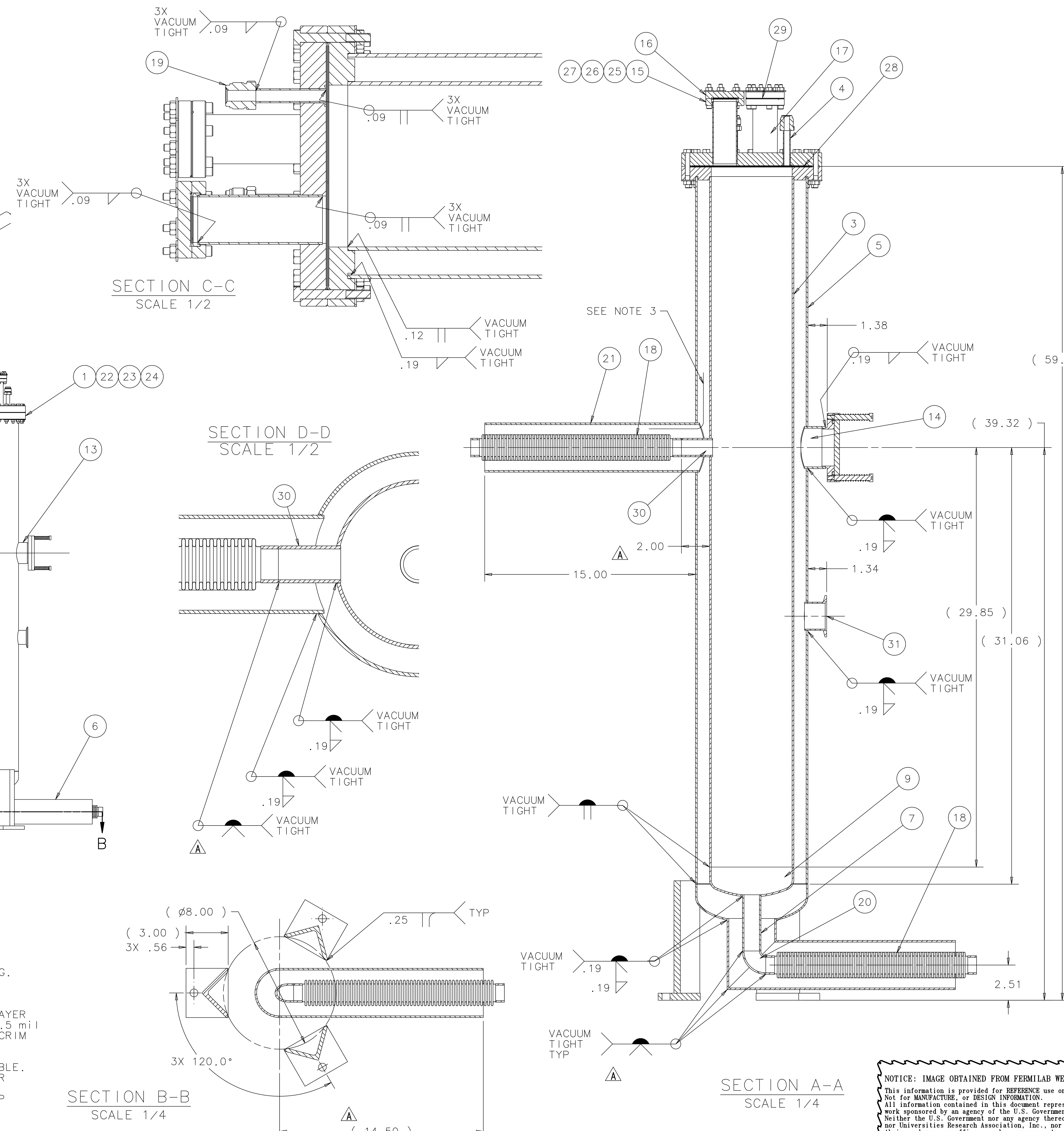
FLARE-MECHANICAL
CRYOGENIC
LAPD TANK CRYO PIPING PHASE 4

SCALE	DRAWING NUMBER	SHEET	REV
3:32 & AS NOTED	3942.330-ME-486264	2 OF 2	A

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	CHANGED LG OF ITEMS 6, 18 & 21 TO REFLECT AS BUILT. WAS BUTT WELD	J. TILLMAN	08-NOV-2010
		T. TOPE	15-NOV-2010





NOTE:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD IN ACCORDANCE WITH ANSI B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION ANS ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ANSI B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. EST WT = 146.86 LBS.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
31		MDC ISO KF-NW/50 HALF NIPPLE STAINLESS STEEL P/N 715109	1
30	MC-466997	BELLOWS PIPE NIPPLE	1
29		MDC GASKET COPPER 1.53 ID #191147	3
28		MDC GASKET COPPER 8" ID #191019	3
27		WASHER TYPE B PLAIN REGULAR 1/4	18
26		NUT HEX 1/4-20 UNC	18
25		SCREW SHCS 1/4-20 X 1.500 LG	18
24		WASHER TYPE B PLAIN REGULAR 3.312	24
23		NUT HEX 5/16-18	24
22		SCREW HHCS 5/16-18 UNC X 2.50 LG	24
A 21	MC-486006	PIPE 3 X SCH 10	1
20		ELBOW 90 IPS 1 SCH 10	1
19	MB-435484	MODIFIED 1/2 MALE NUT	3
A 18		BELLOWS BRAIDED IPS 1X15.00 LG	2
17		304 STAINLESS STEEL TUBE 1 3/4 OD X .065 WALL X 4.44 LG	3
16		MDC DEL-SEAL NON-ROTATABLE CF FLANGE 2 3/4 OD P/N 110008	3
15		MDC DEL-SEAL ROTATABLE CF FLANGE 2 3/4 OD P/N 100043	3
14	MB-466996	TUBE 3 OD X .12 WALL X 1.75 LG	1
13	MB-106391	VACUUM POP RELIEF 2.625 PORT	1
12	MC-466785	PLATE .50 X 3 X 3.5	3
11	MC-466765	ANGLE STL 2.5 X 1/4 X 8.00 LG	3
10	MC-486008	CAP 8 TUBE X .109 WALL 3.500 HOLE	1
9	MC-486007	CAP 6 TUBE X .120 WALL 1.312 HOLE	1
8	MC-486002	PIPE 3 SCH 10 X 3.312 LG MITER	1
7	MC-466999	PIPE 1 SCH 10 X 4.00 LG	1
A 6	MC-486001	PIPE 3 SCH 10 X 12.12 LG MITER	1
5	MC-486005	TUBE 8 OD X .12 WALL 50.31 LG	1
4	MC-486003	TUBE 1/2 OD X .049W X 2.50 LG	3
3	MC-486004	TUBE 6 OD X .12W X 49.12 LG	1
2	MC-486009	FLANGE CF-10 OD 6 HOLES	1
1	MC-466998	FLANGE CF-10 OD 6 TUBE	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	T.TOPE	06-MAY-2010
± .06	± ---	± ---	DRAWN	S.KINDELBERGER	12-MAY-2010
			CHECKED	J.RAUCH	06-JUN-2010
			APPROVED	T.TOPE	11-JUN-2010

1. BREAK ALL SHARP EDGES .031 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON: ME-486000

MATERIAL: SEE PARTS LIST ABOVE

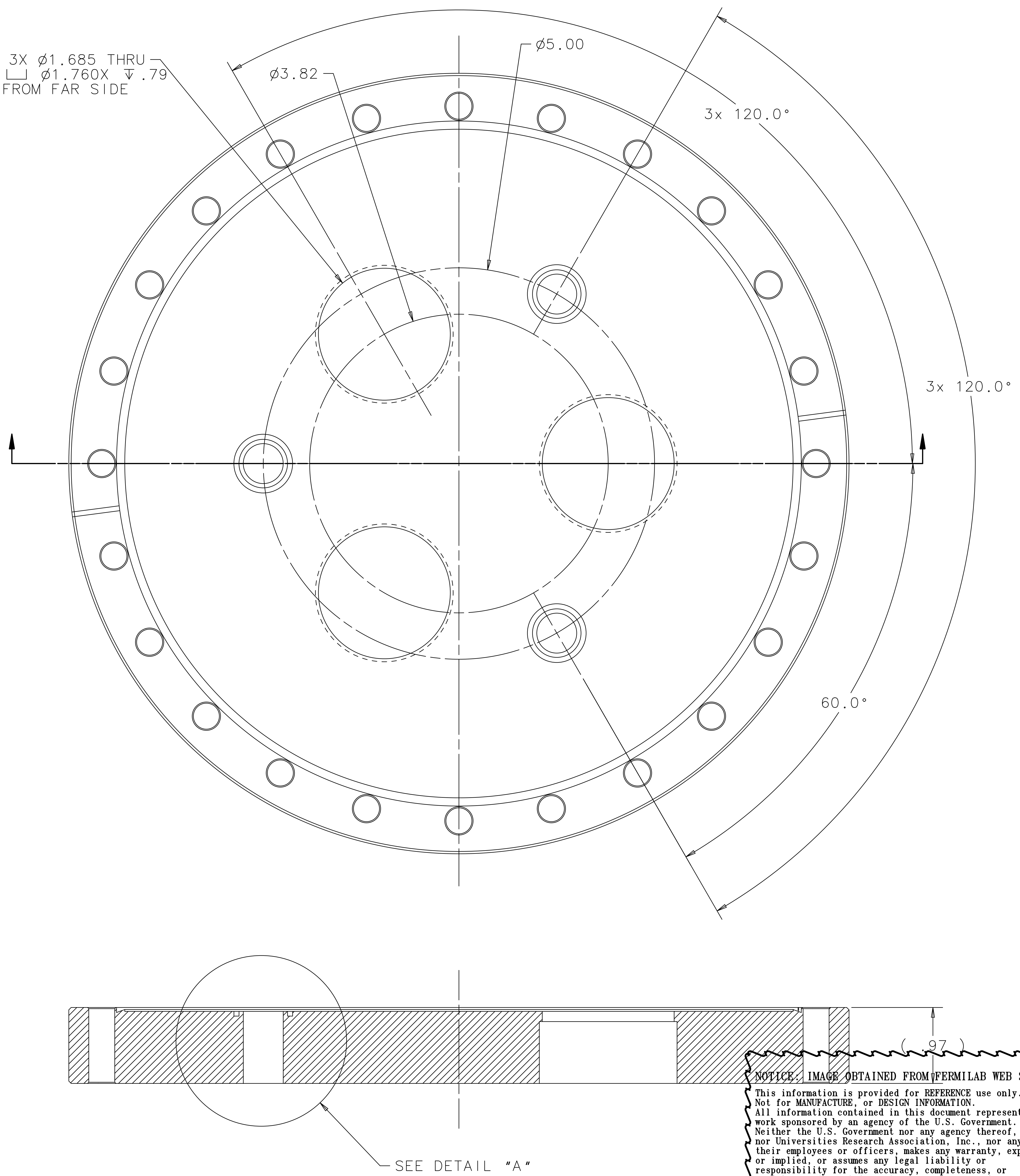
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

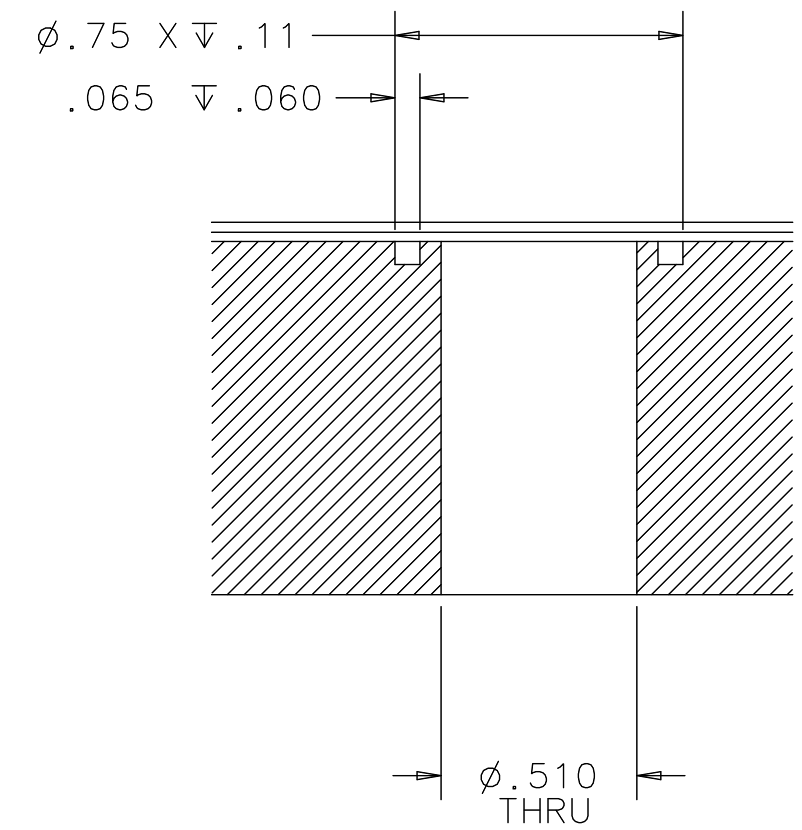
FLARE-GENERAL
PRELIMINARY DESIGN AND CONCEPT
PURITY MONITOR VESSEL WELD

SCALE	DRAWING NUMBER	SHEET	REV
1/8 & NOTED	3942.330-MD-466995	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE





DETAIL "A"
SCALE 2:1
TYP THREE HOLES

EST WT = 17.96

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	T.TOPE	06-MAY-2010
.XX	.XXX	ANGLES	DRAWN	S.KINDELBERGER	06-MAY-2010
± .03	± .005	± .5°	CHECKED	J.RAUCH	02-JUN-2010
			APPROVED	T.TOPE	11-JUN-2010

1. BREAK ALL SHARP EDGES .031 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON: MD-466995

MATERIAL: FLANGE MDC110032 MODIFIED

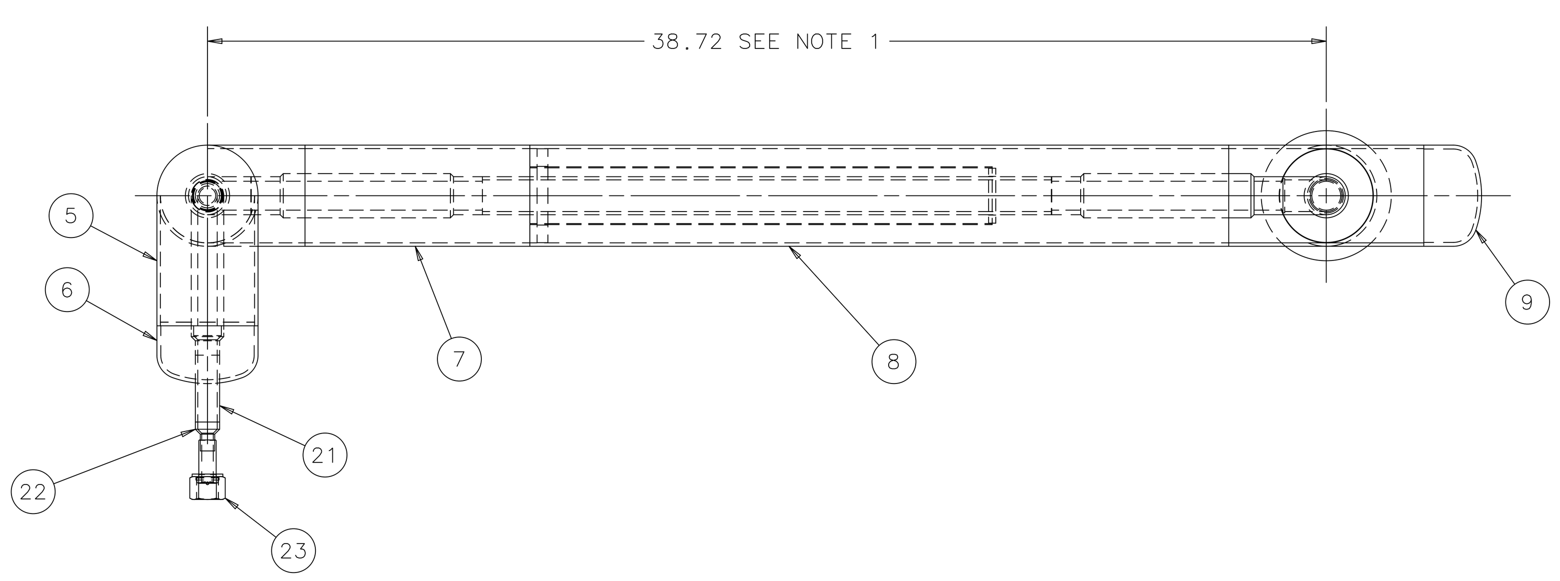
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

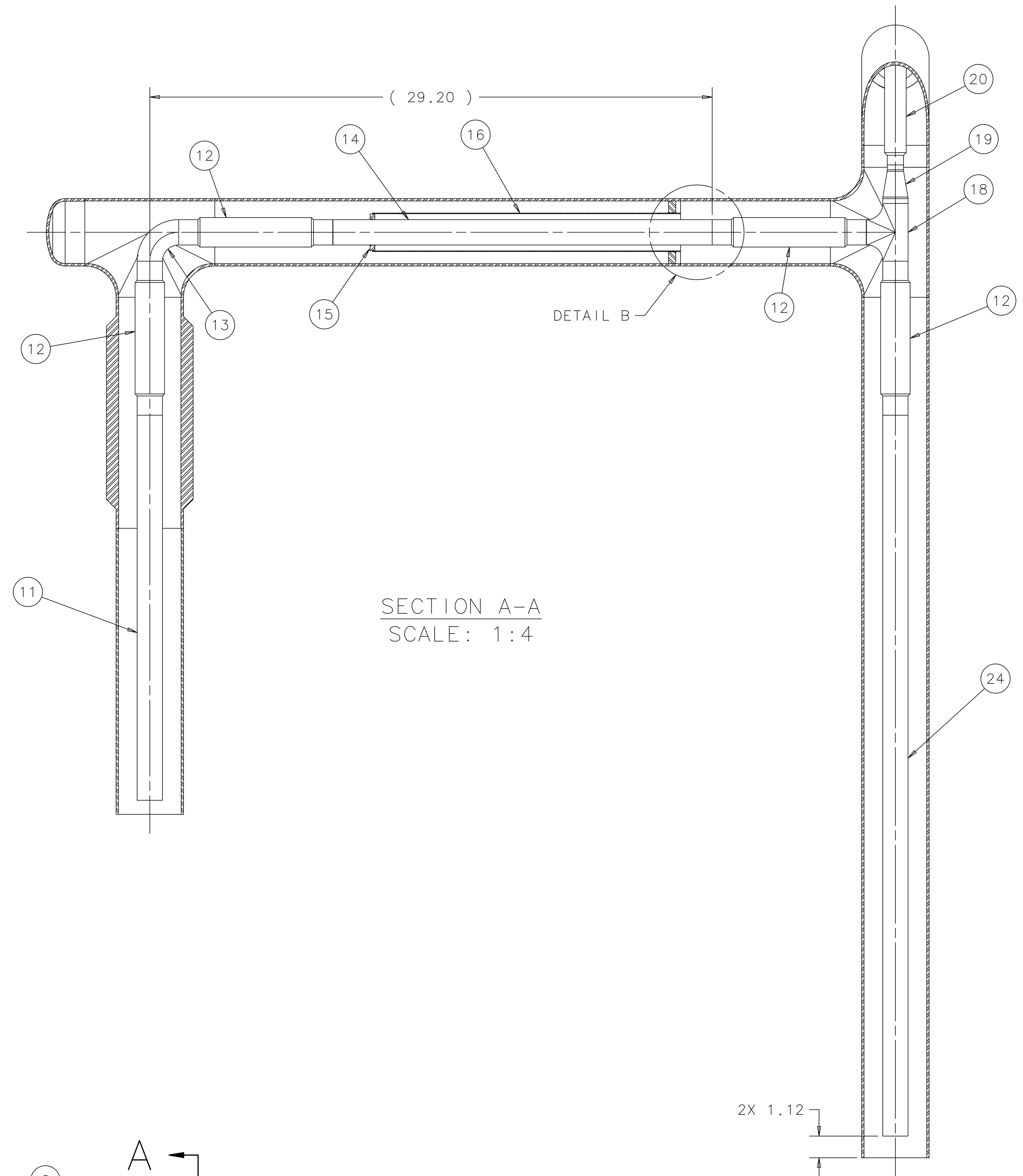
FLARE-MECHANICAL
INLINE PURITY MONITOR VESSEL
FLANGE CF10 OD 6 HOLES

SCALE	DRAWING NUMBER	SHEET	REV
1:1	3942.330-MC-486009	1 OF 1	

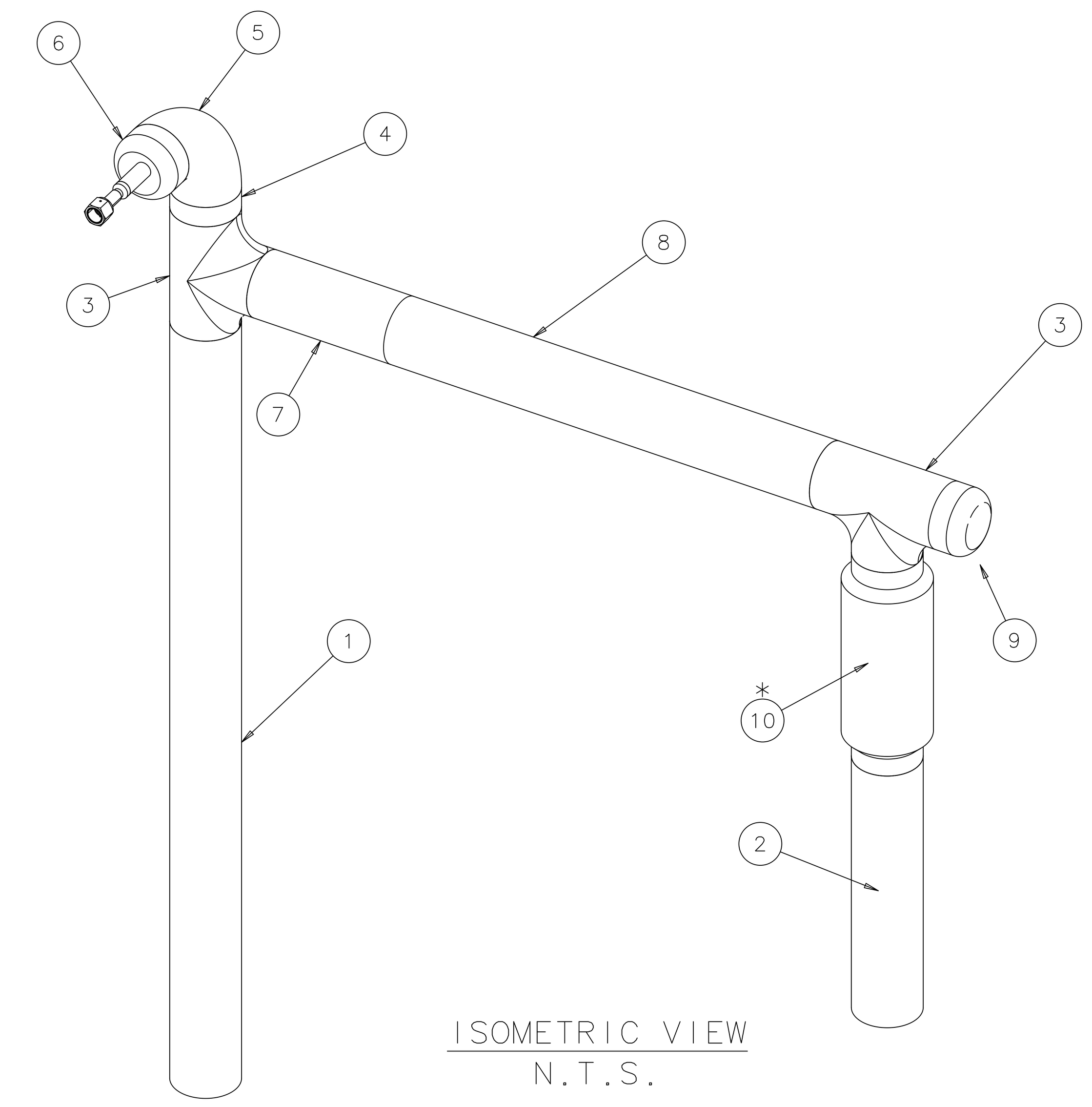
CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE

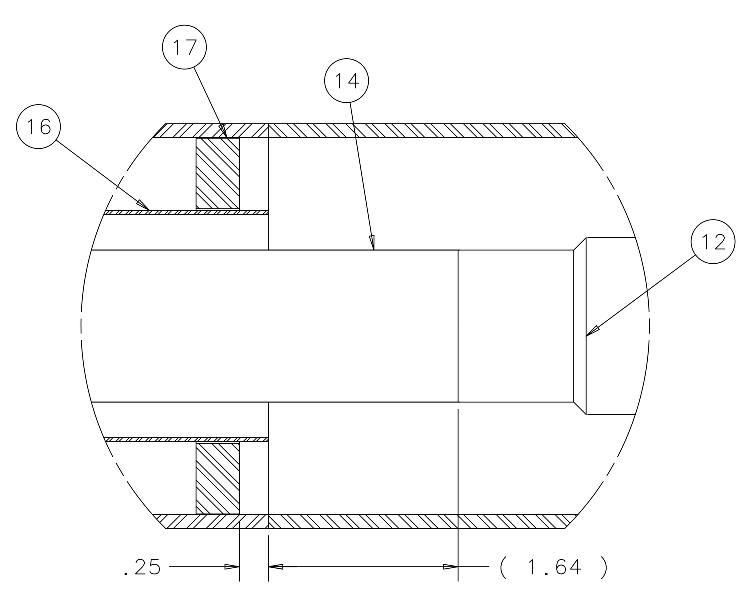




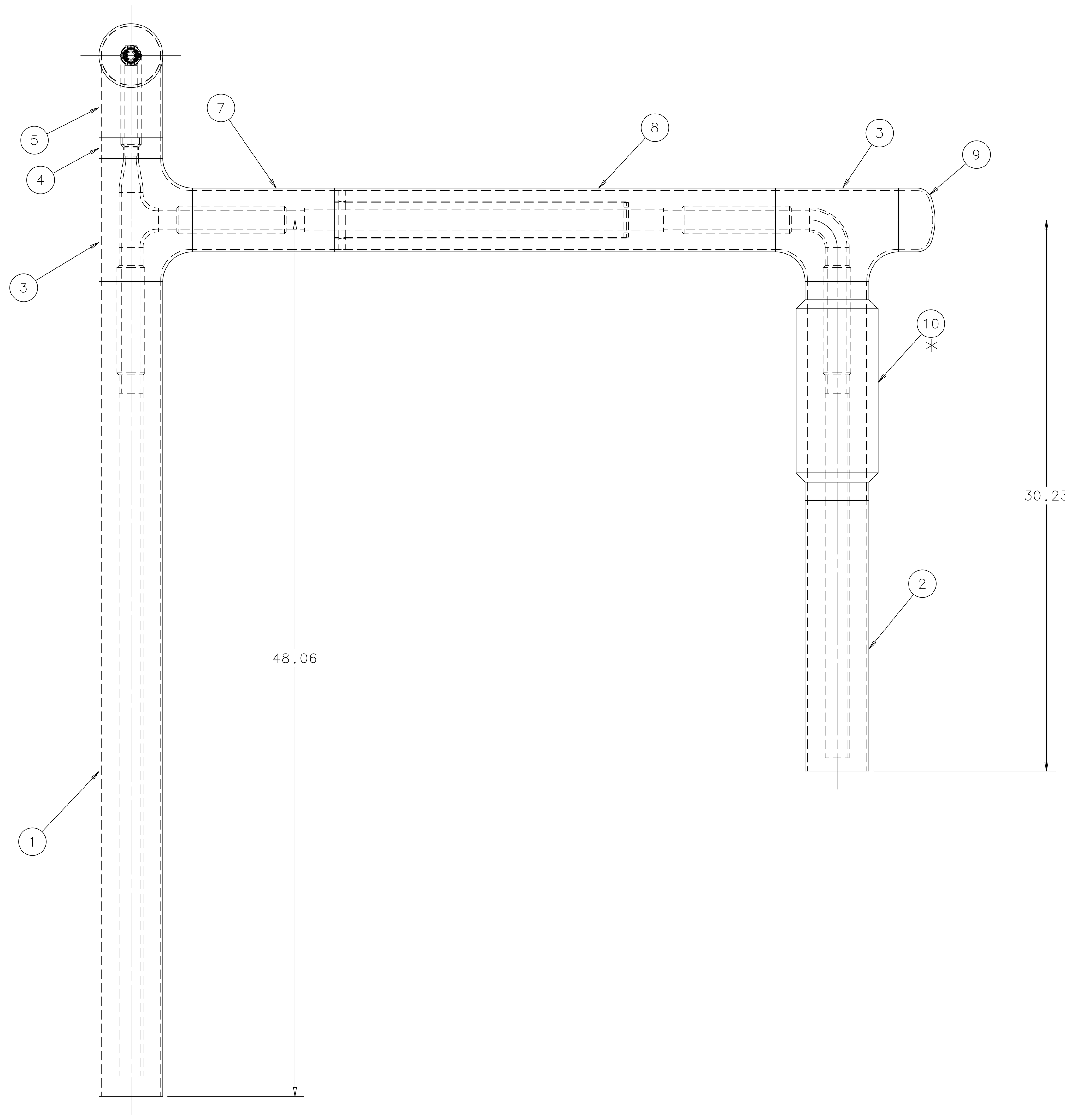
SECTION A-A
SCALE: 1:4

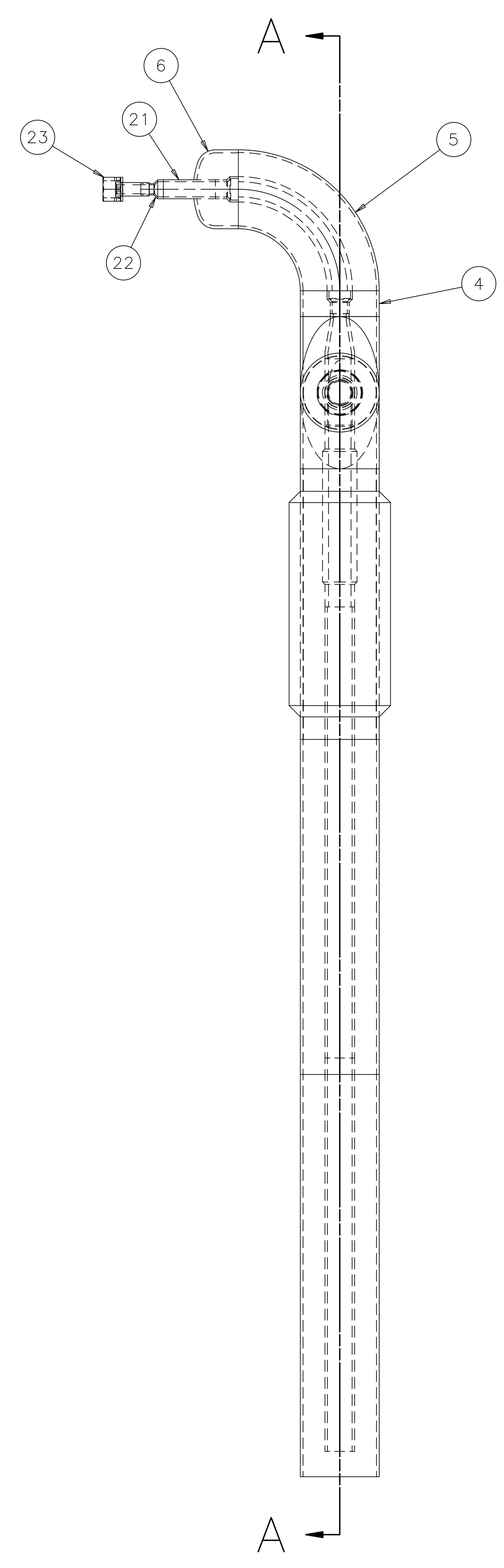


ISOMETRIC VIEW
N.T.S.



DETAIL B
SCALE: 1:1





NOTES:

1. FINAL DIMENSION BETWEEN VERTICAL SEGMENTS WILL BE A FIELD FIT. DO NOT WELD UNTILL PHASE 3 (ME-486146) & PHASE 4 (ME-486264) ARE IN PLACE.

2. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC

3. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHAL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.

4. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS (MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM CLOTH (WEIGHT OF 0.5 oz/yard 2.

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.

5. THERE ARE APPROX. 28 WELDS.

* SPECIAL NOTE: THE 3" X 12" FLEX HOSES (ITEM 6) SHOULD BE RESTRAINED BY THREE Ø3/8" THREADED RODS.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
24	COML	PIPE, 1" SCH 10 X 34.44; 304SS	1
23	COML	VCR CONNECTOR, 1/2" O.D. TUBE	1
22	MB-486152	ADAPTER, 1/2" PIPE X 1/2" TUBE	1
21	COML	PIPE, 1/2" SCH 10 X 2.00; 304SS	1
20	COML	FLEX HOSE, 1/2" IPS ENDS X 9.25 OAL	1
19	COML	RED. CONC.; 1 X 1/2 SCH 10 304SS	1
18	COML	TEE, STRAIGHT, 1" SCH 10; 304SS	1
17	MB-486415	ADAPTER 3IPS X 2" 20GA TUBE	1
16	COML	TUBE, 2 X .035 WALL X 16.00; 304SS	1
15	MB-486414	ADAPTER 2" 20GA TUBE X 1IPS	1
14	COML	PIPE, 1" SCH 10 X 19.69; 304SS	1
13	COML	ELBOW, 1" SCH 10 LR; 304 SS	1
12	COML	FLEX HOSE 1" IPS ENDS X 8.00 OAL	4
11	COML	PIPE, 1" SCH 10 X 20.00; 304SS	1
10	COML	FLEX HOSE 3" IPS ENDS X 12.00 OAL	1
9	COML	PIPE CAP, 3" SCH 10; 304SS	1
8	COML	PIPE, 3" SCH 10 X 24.19; 304SS	1
7	COML	PIPE, 3" SCH 10 X 7.78; 304SS	1
6	MB-486084-3	PIPE CAP, 3" SCH 10 X 1" IPS	1
5	COML	ELBOW, 3" SCH 10 LR; 304SS	1
4	COML	PIPE, 3" SCH 10 X 1.14; 304SS	1
3	COML	TEE, STRAIGHT, 3" SCH 10; 304SS	2
2	COML	PIPE, 3" SCH 10 X 14.86; 304SS	1
1	COML	PIPE, 3" SCH 10 X 44.69; 304SS	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX ± .06	.XXX ± ---	ANGLES ± ---	ORIGINATOR	T.TOPE	11-NOV-2010
			DRAWN	J.TILLMAN	11-NOV-2010
			CHECKED	W.CYKO	04-JAN-2011
			APPROVED	T.TOPE	04-JAN-2011

1. BREAK ALL SHARP EDGES MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES √
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE

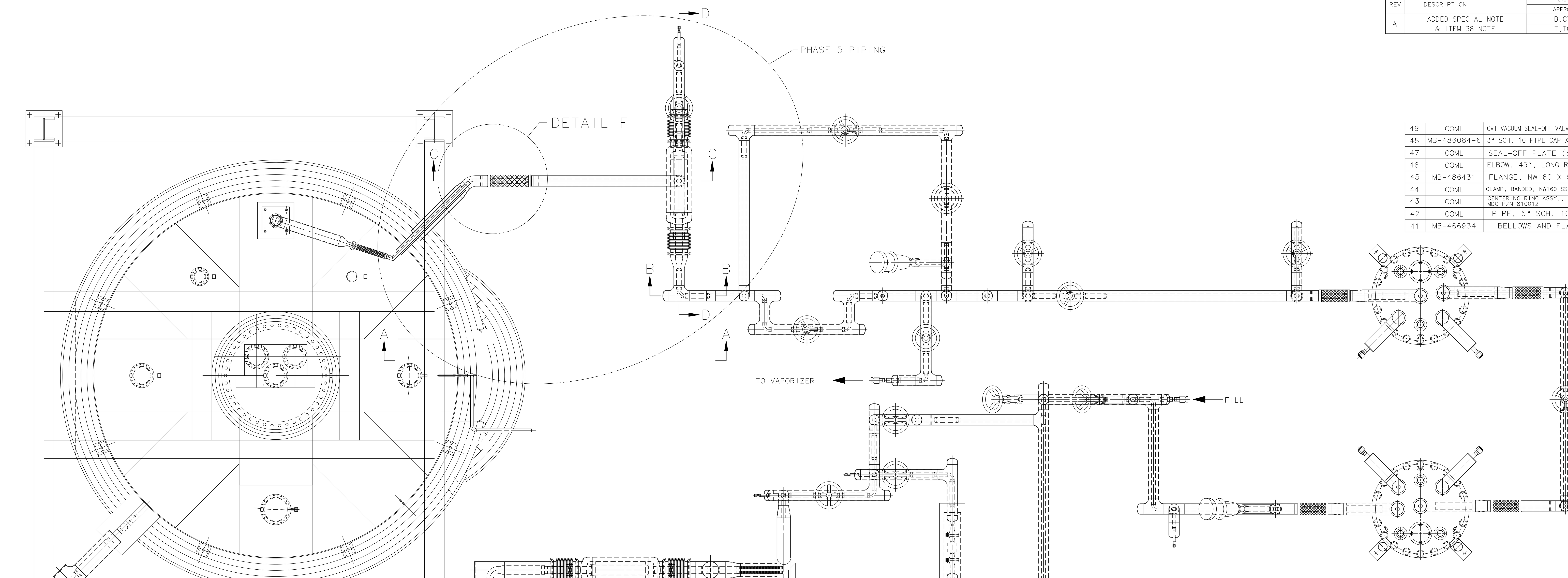
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE-MECHANICAL
CRYOGENIC
LAPD FILTER BYPASS PIPE ASSY

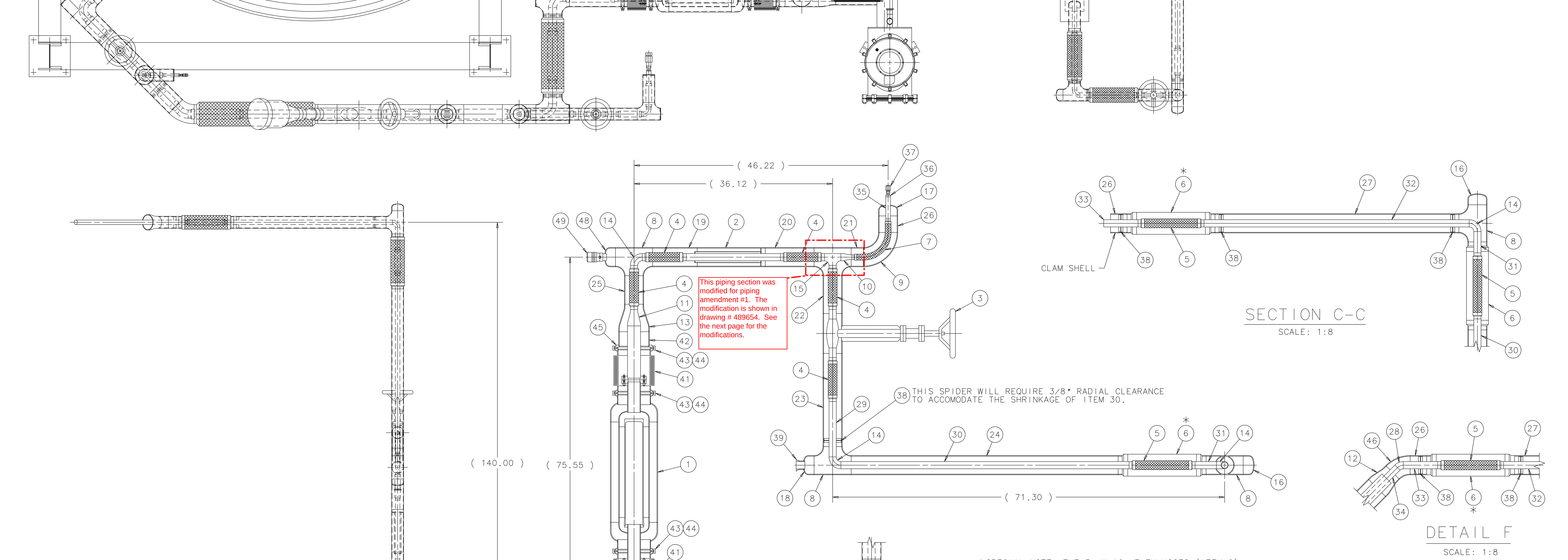
SCALE	DRAWING NUMBER	SHEET	REV
1:4 & AS NOTED	3942.320-ME-486411	1 OF 1	

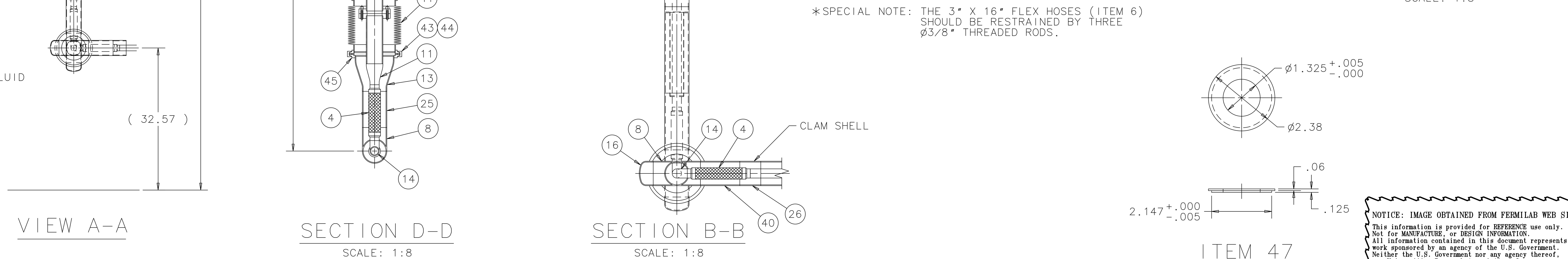
CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	ADDED SPECIAL NOTE & ITEM 38 NOTE	B.CYKO / T.TOPE	24 JAN 2011 / 24 JAN 2011



49	COML	CVI VACUUM SEAL-OFF VALVE, V-1046-31, 1"	1
48	MB-486084-6	3" SCH. 10 PIPE CAP X CVI V-1046 1"	1
47	COML	SEAL-OFF PLATE (SEE DRAWING)	1
46	COML	ELBOW, 45°, LONG R. 3" SCH. 10	1
45	MB-486431	FLANGE, NW160 X 5" IPS PIPE	2
44	COML	CLAMP, BANDED, NW160 SS, MDC P/N 540005	4
43	COML	CENTERING RING ASSY., NW160 SS/VITON, MDC P/N 810012	4
42	COML	PIPE, 5" SCH. 10 X 2.63 LG.	1
41	MB-466934	BELLOWS AND FLANGE ASSY.	2





40	COML	PIPE, 3" SCH. 10 X 5.63 LG.	1
39	COML	HALF NIPPLE, NW40, 1.50 O.D. X 1.58 LG.	1
38	COML	G-10 CRYO SPIDER	4
37	COML	VCR CONNECTOR, 1/2" O.D. TUBE	1
36	MB-486152	ADAPTER, 1/2" PIPE X 1/2" O.D. TUBE	1
35	COML	PIPE, 1/2" SCH. 10 X 4.00 LG.	1
34	COML	REFERENCE DWG.ME-482227 & MD-486219	1
33	COML	PIPE, 1" SCH. 10 X 6.25 LG.	1
32	COML	PIPE, 1" SCH. 10 X 48.25 LG.	1
31	COML	PIPE, 1" SCH. 10 X 3.88 LG.	1
30	COML	PIPE, 1" SCH. 10 X 52.43 LG.	1
29	COML	PIPE, 1" SCH. 10 X 10.07 LG.	1
28	COML	ELBOW, 45°, LONG R. 1" SCH. 10	1
27	COML	PIPE, 3" SCH. 10 X 44.36 LG.	1
26	COML	PIPE, 3" SCH. 10 X 3.00 LG.	3
25	COML	PIPE, 3" SCH. 10 X 5.18 LG.	2
24	COML	PIPE, 3" SCH. 10 X 48.56 LG.	1
23	COML	PIPE, 3" SCH. 10 X 16.94 LG.	1
22	COML	PIPE, 3" SCH. 10 X 6.88 LG.	1
21	COML	PIPE, 3" SCH. 10 X 2.22 LG.	1
20	COML	PIPE, 3" SCH. 10 X 8.88 LG.	1
19	COML	PIPE, 3" SCH. 10 X 8.13 LG.	1
18	MB-486084-4	PIPE CAP, 3" SCH. 10 X 1.50 O.D. TUBE	1
17	MB-486084-5	PIPE CAP, 3" SCH.10 X 1/2" IPS	1
16	COML	PIPE CAP, 3" SCH.10	2
15	COML	TEE, STRAIGHT, 1" SCH. 10	1
14	COML	ELBOW, 90°,LONG R., 1" SCH.10	4
13	COML	REDUCER, CONCENTRIC, 5" X 3" SCH. 10	2
12	COML	REDUCER, CONCENTRIC, 4" X 3" SCH. 10	1
11	COML	REDUCER, CONCENTRIC, 2" X 1" SCH. 10	2
10	COML	REDUCER, CONCENTRIC, 1" X 1/2" SCH. 10	1
9	COML	ELBOW, 90°, LONG R.,3" SCH. 10	5
8	COML	TEE, STRAIGHT, 3" SCH. 10	1
7	FURNISHED	FLEX HOSE, 1/2" IPS ENDS X 12.25 OAL	2
6	FURNISHED	FLEX HOSE, 3" IPS ENDS X 16.00 OAL	2
5	FURNISHED	FLEX HOSE, 1" IPS ENDS X 12.00 OAL	2
4	FURNISHED	FLEX HOSE, 1" IPS ENDS X 8.00 OAL	7
3	FURNISHED	1" IPS GLOBE VALVE, EDEN	1
2	MB-486433	VACUUM BREAK ASSEMBLY	1
1	MD-466888	ARGON FILTER ASSEMBLY	1
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.

PARTS LIST

NOTE:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC

2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.

3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM CLOTH (WEIGHT OF 0.5 oz./yard 2). ^

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.

4. THERE ARE APPROX. 102 WELDS.

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	T.TOPE	29-NOV-2010
.XX	.XXX	ANGLES	DRAWN	W.CYKO	29-NOV-2010
± .06	± -----	±-----	CHECKED	J.TILLMAN	27-DEC-2010
			APPROVED	T.TOPE	27-DEC-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS:U.S.INCH

USED ON

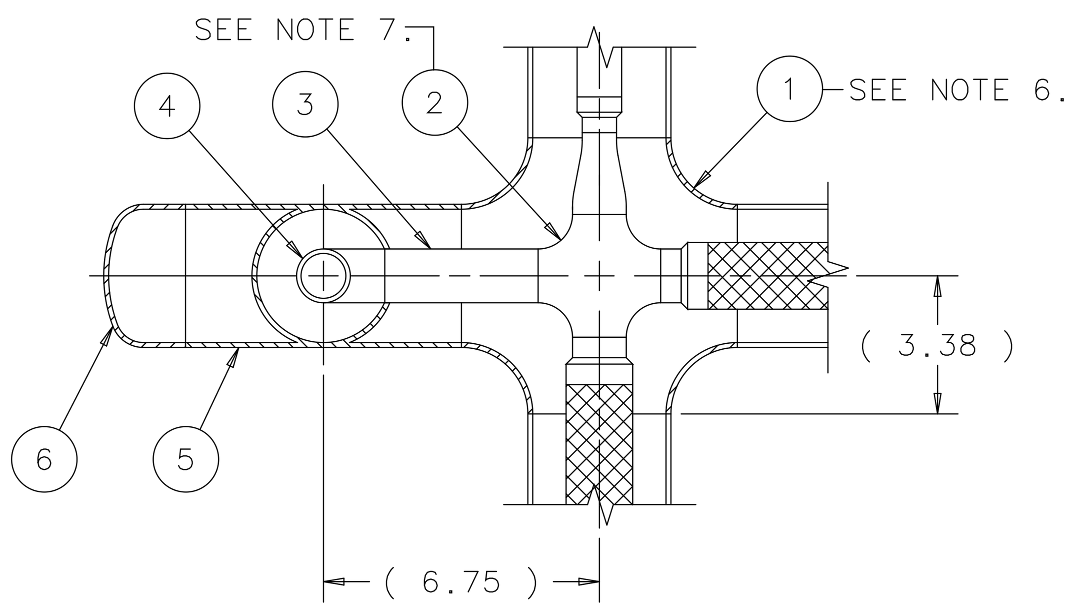
MATERIAL
SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE-MECHANICAL CRYOGENIC LAPD TANK CRYO PIPING PHASE 5

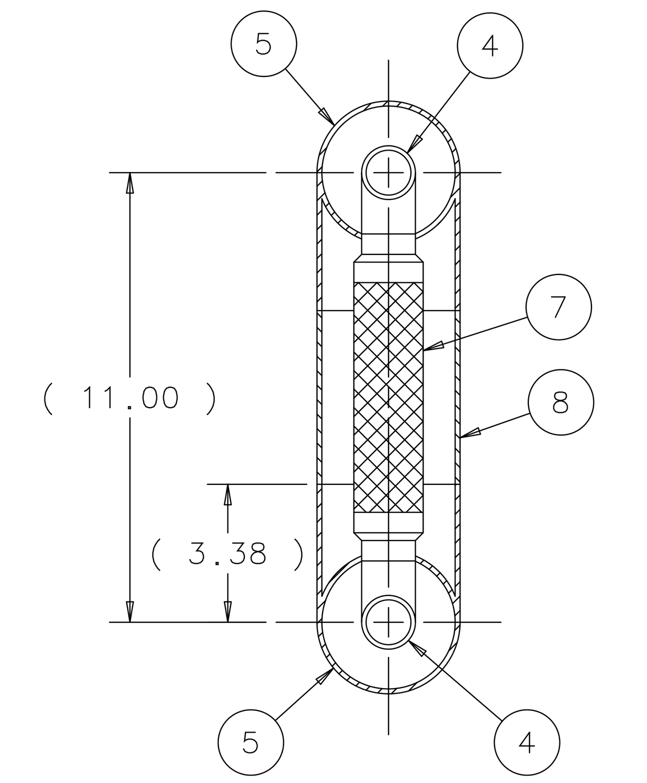
SCALE	DRAWING NUMBER	SHEET	REV
1:5/64 & AS NOTED	3942.330-ME-486428	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT



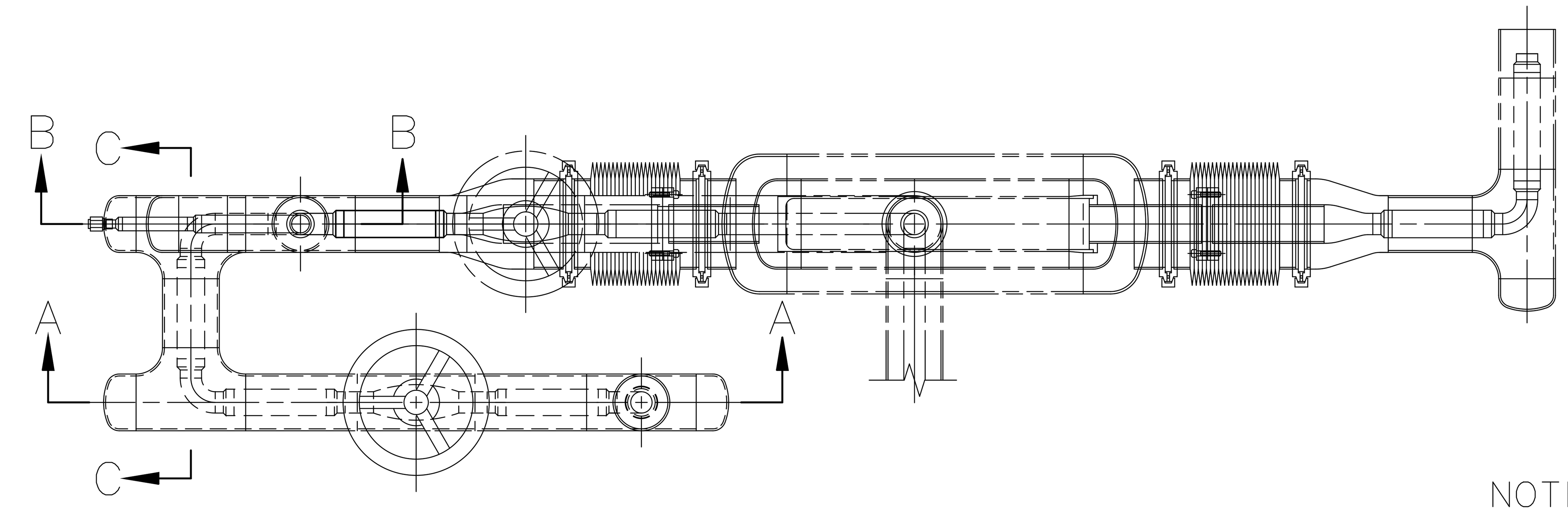
SECTION B-B

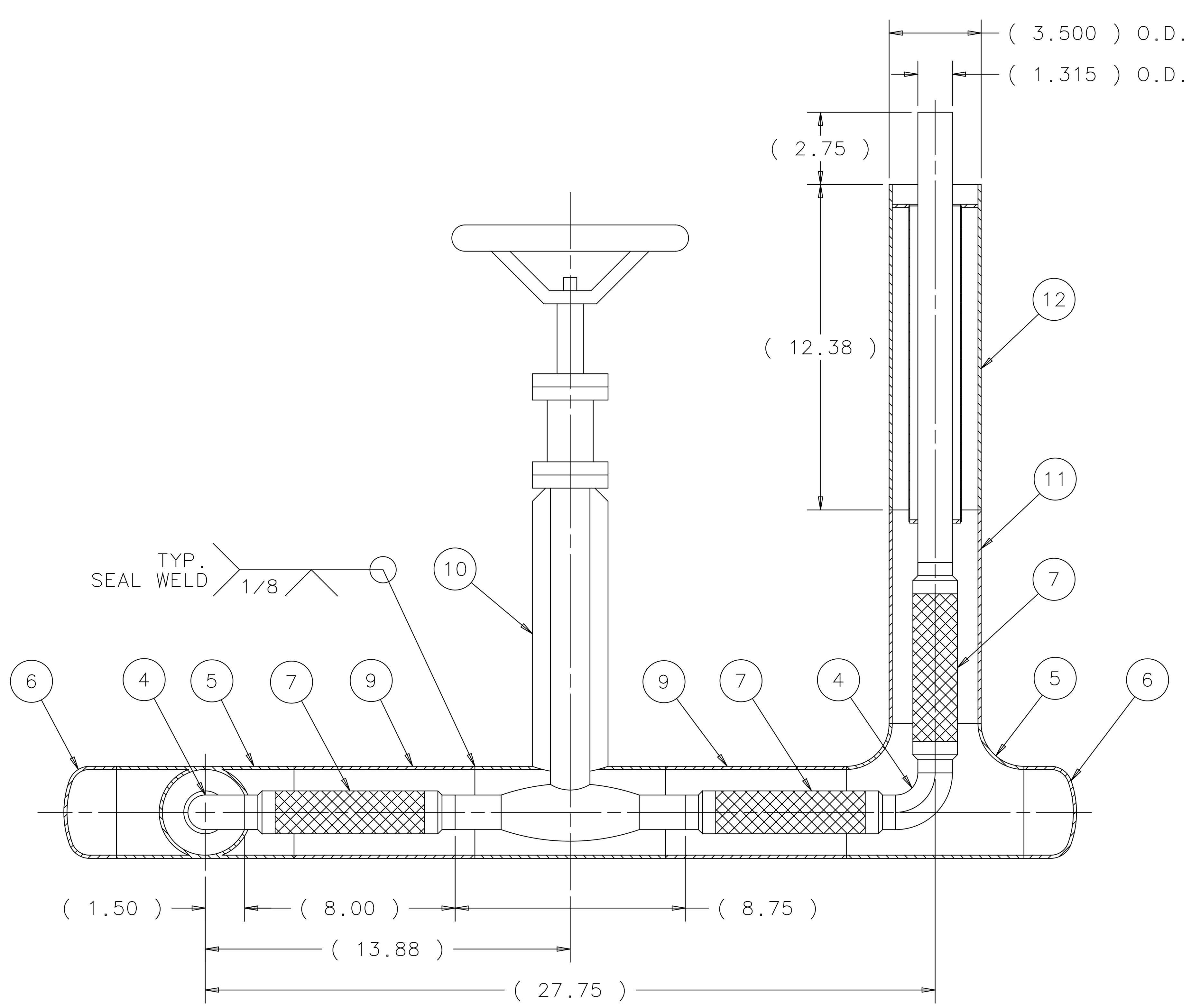
SCALE: 1:4



SECTION C-C

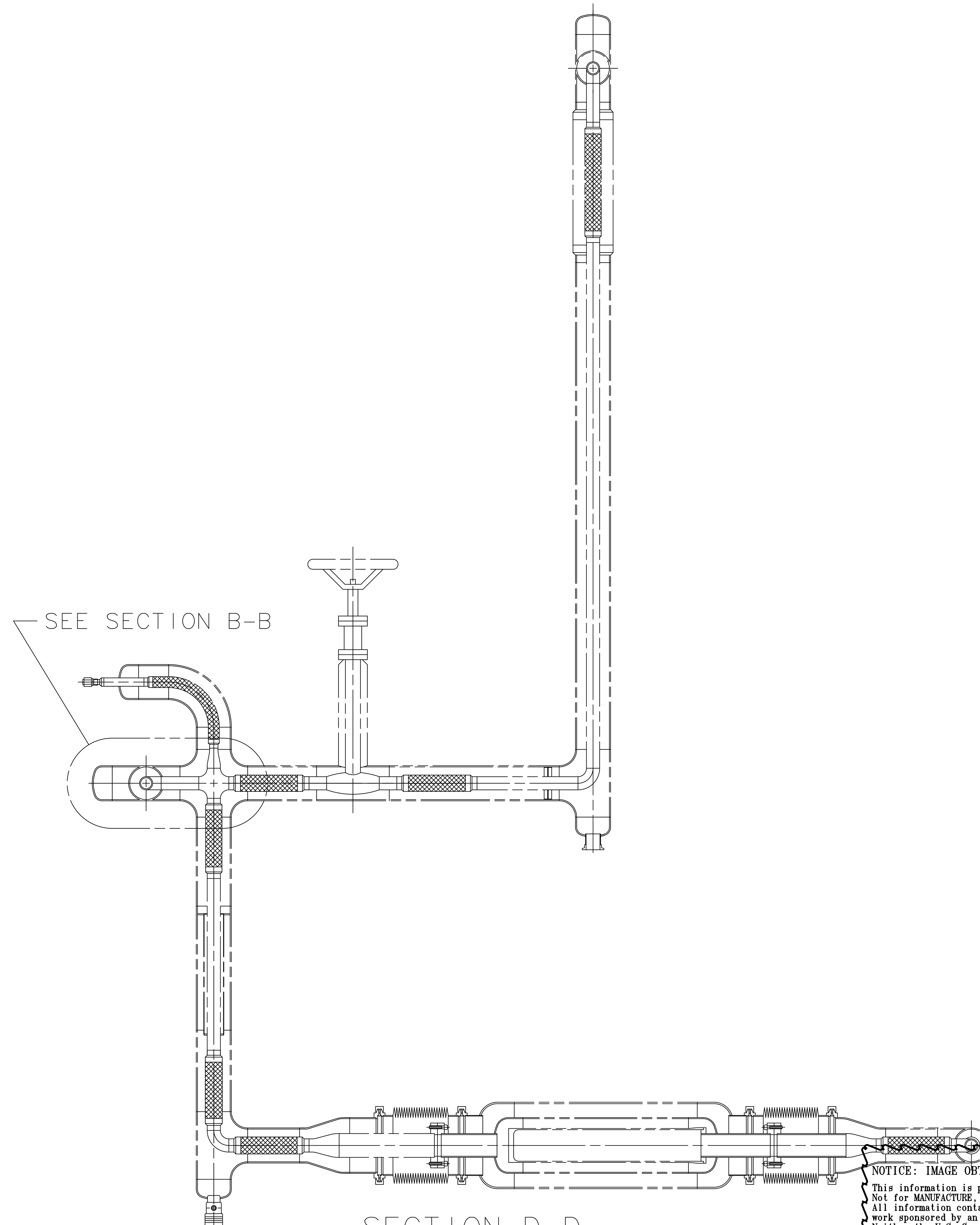
SCALE: 1:4





SECTION A-A

SCALE: 1:4



SECTION D-D FROM DRAWING ME-486428

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE

NOTES:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS, VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. THERE ARE APPROX. 25 WELDS.
5. UNLESS OTHERWISE SPECIFIED, ALL MATERIAL TO BE STAINLESS STEEL TYPE 304.
6. THIS ITEM REPLACES 3" SCH. 10 TEE SHOWN ON DRAWING ME-486428 SECTION D-D ITEM 15.
7. THIS ITEM REPLACES 1" SCH. 10 TEE SHOWN ON DRAWING ME 486428 SECTION D-D ITEM 15.

	ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
	12	MB-486433	VACUUM BREAK ASSEMBLY	1
	11	COML.	PIPE, 3" SCH. 10 X 8.12 LG.	1
	10	FURNISHED	1" IPS GLOBE VALVE, EDEN	1
	9	COML.	PIPE, 3" SCH. 10 X 6.88 LG.	2
	8	COML.	PIPE, 3" SCH. 10 X 4.25 LG.	1
	7	FURNISHED	FLEX HOSE, 1" IPS ENDS X 8.00 OAL	4
	6	COML.	PIPE CAP, 3" SCH. 10	3
	5	COML.	TEE, STRAIGHT, 3" SCH. 10	3
	4	COML.	ELBOW, 90°, LONG R., 1" SCH. 10	3
	3	COML.	PIPE, 1" SCH. 10 X 3.75 LG.	1
SEE NOTE 7.	2	COML.	CROSS, STRAIGHT, 1" SCH. 10	1
SEE NOTE 6.	1	COML.	CROSS, STRAIGHT, 3" SCH. 10	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	T.TOPE	17-APR-2012
.XX	.XXX	ANGLES	DRAWN	W.CYKO	17-APR-2012
± .06	± - -	± - -	CHECKED	J.RAUCH	20-APR-2012
			APPROVED	T.TOPE	20-APR-2012

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M 1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: INCHES

USED ON

MATERIAL
SEE PARTS LIST ABOVE

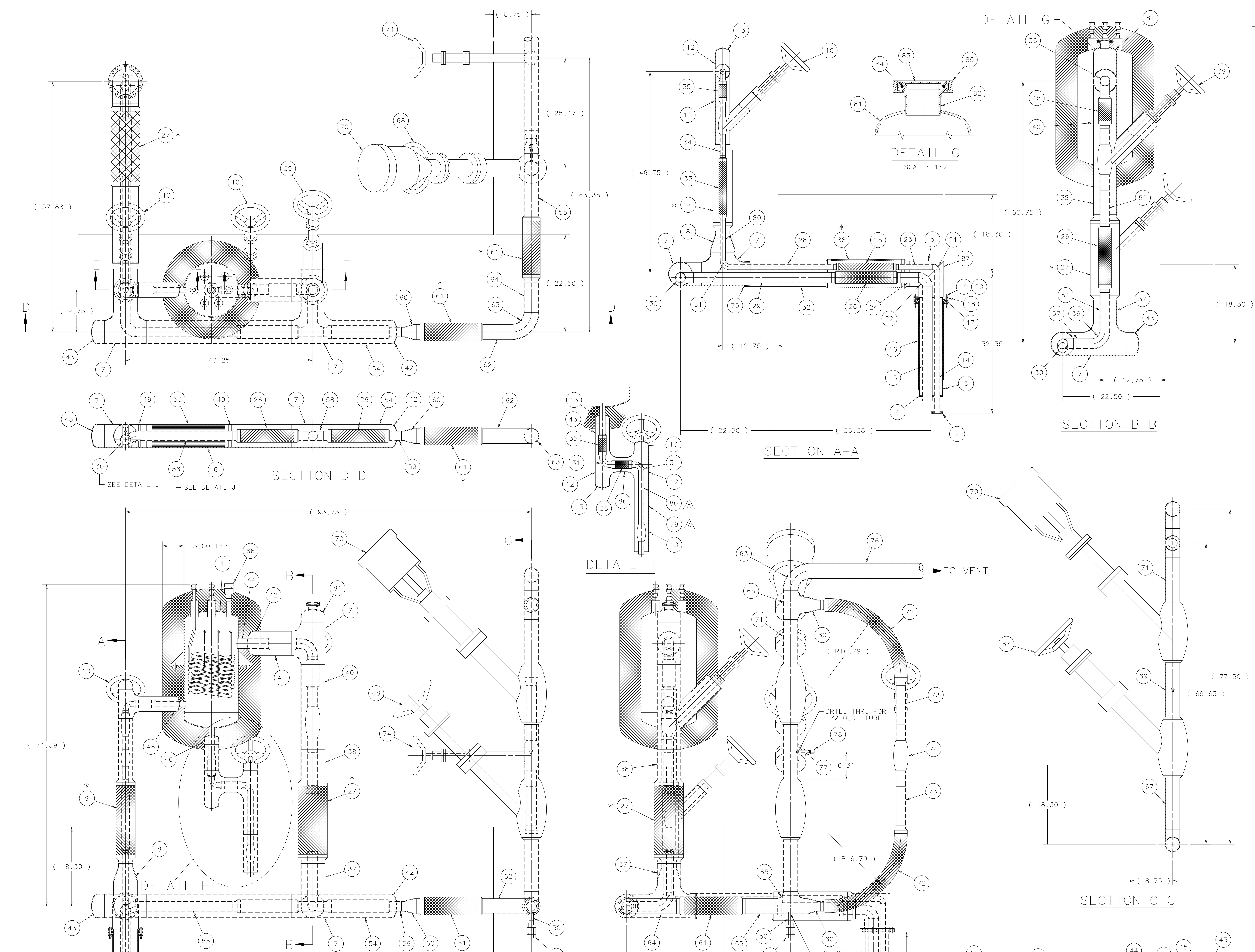
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

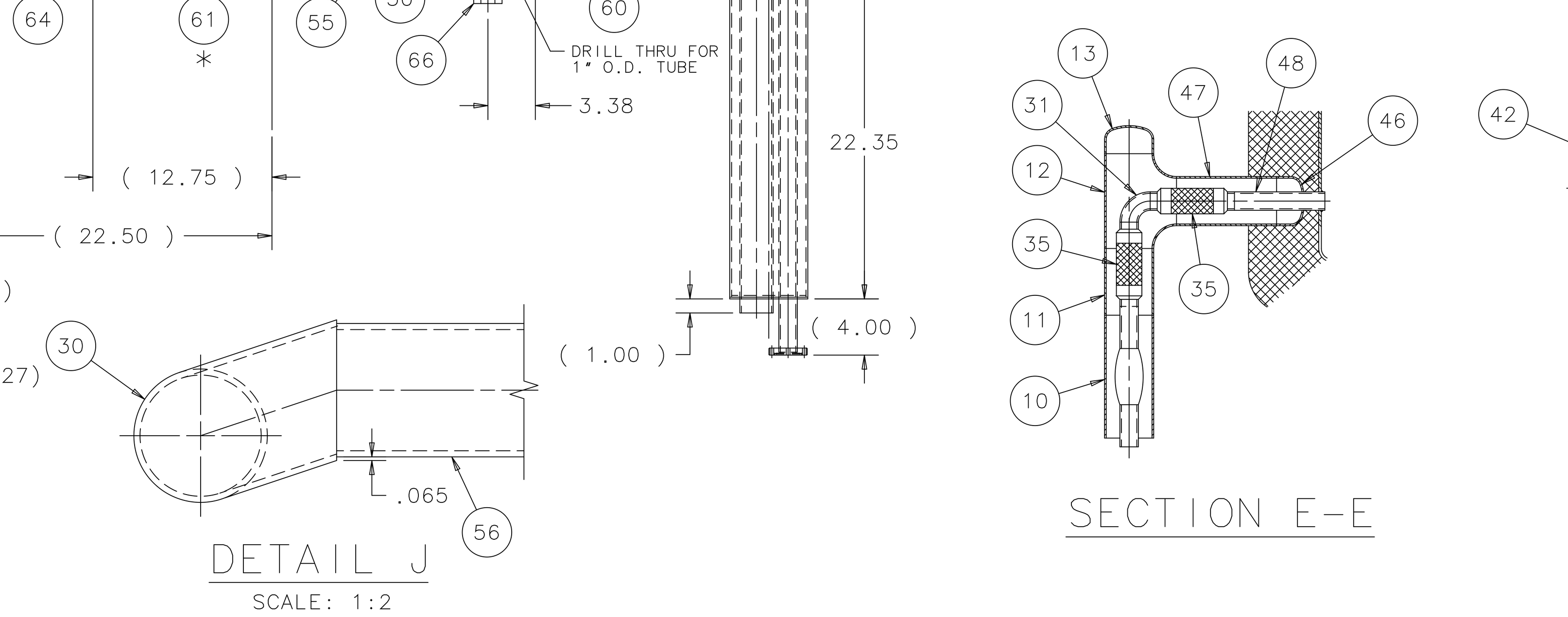
FLARE-MECHANICAL
CRYOGENIC
LAPD TIE-IN TO LBNE 35T PIPING A

SCALE	DRAWING NUMBER	SHEET	REV
1:8 & AS NOTED	3942.330-MD-489654	1 OF 1	

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	REVISED DETAIL H; ITEMS 79 & 80, CHANGED QTY. OF ITEM 7 FROM "1" TO "5", ADDED NOTES.	B. CYKO	09-09-10
		T. TOPE	09-09-10





ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
88	FURNISHED	FLEX HOSE, 6" O.D. TUBE X .065 WALL ENDS X 20.00 LG.	1
87	MB-486101	TUBING, 6" O.D. X .065 WALL X 8.31 LG. (45°)	1
86	COML	PIPE, 3" SCH. 10 X 2.25 LG.	1
85	COML	FLANGE ASSY. NW50, MDC P/N 700004	1
84	COML	CENTERING RING, NW50, MDC P/N 710003	1
83	COML	FLANGE, BLANK, NW50, MDC P/N 712003	1
82	COML	HALF NIPPLE, NW50 X 1.58 LG., MDC P/N 715109	1
81	MB-486084-2	PIPE CAP, 5" SCH. 10 X 2" O.D. TUBE	1
80	COML	PIPE, 1" SCH. 10 X 9.25 LG.	2
79	COML	PIPE, 3" SCH. 10 X 8.00 LG.	1
78	COML	1/2" VCR MALE X FEMALE FITTING	1
77	COML	TUBING, 1/2" O.D. X .049 WALL X 3.00 LG.	1
76	COML	PIPE, 3" SCH. 10	AS REQD.
75	MB-486097	TRANSITION RING	1
74	FURNISHED	2" MANUAL GLOBE VALVE, W/O VACUUM JACKET	1
73	COML	PIPE, 2" SCH. 10 X 9.09 LG.	2
72	FURNISHED	FLEX HOSE, 2" IPS ENDS X 30.00 LG.	2
71	COML	PIPE, 3" SCH. 10 X 10.25 LG.	1
70	FURNISHED	3" Y PATTERN REMOTE VALVE, EDEN BC-02146-8135	1
69	COML	PIPE, 3" SCH. 10 X 12.63 LG. W/VCR PORT	1
68	FURNISHED	3" Y PATTERN MANUAL VALVE, EDEN BC-02146-8134	1
67	COML	PIPE, 3" SCH. 10 X 12.00 LG.	1
66	COML	1" VCR MALE X FEMALE FITTING	2
65	COML	TEE, STRAIGHT, 3" SCH. 10	1
64	COML	PIPE, 3" SCH. 10 X 7.00 LG.	1
63	COML	ELBOW, 90°, LONG RADIUS, 3" SCH. 10	1
62	COML	PIPE, 3" SCH. 10 X 6.00 LG.	1
61	FURNISHED	FLEX HOSE, 3" IPS ENDS X 16.00 LG.	2
60	COML	REDUCER, CONCENTRIC, 2" X 3" SCH. 10	2
59	COML	PIPE, 2" SCH. 10 X 2.00 LG.	1
58	COML	TEE, STRAIGHT, 2" SCH. 40	1
57	COML	PIPE, 2" SCH. 10 X 4.25 LG.	1
56	COML	PIPE, 2" SCH. 10 X 22.33 LG.	1
55	COML	PIPE, 3" SCH. 10 X 7.00 LG.	1
54	COML	PIPE, 5" SCH. 10 X 14.50 LG.	1
53	COML	PIPE, 5" SCH. 10 X 33.50 LG.	1
52	COML	PIPE, 2" SCH. 10 X 7.63 LG.	1
51	COML	PIPE, 2" SCH. 10 X 8.88 LG.	1
50	COML	TUBING, 1" O.D. X .065 WALL X 3.00 LG.	1
49	MB-466935	CRYO LINE SPACER	2
48	COML	PIPE, 1" SCH. 10 X 6.50 LG.	1
47	COML	PIPE, 3" SCH. 10 X 7.13 LG.	1
46	MB-486084-3	PIPE CAP, 3" SCH. 10 X 1" IPS	2
45	FURNISHED	FLEX HOSE, 2" IPS PIPE ENDS X 8.00 LG.	2
44	COML	PIPE, 2" SCH. 10 X 6.50 LG.	1
43	COML	PIPE, 3" SCH. 10 X 6.06 LG.	1
42	MB-486084-1	PIPE CAP, 5" SCH. 10 X 2" IPS	2
41	COML	PIPE, 5" SCH. 10 X 7.25 LG.	1
40	COML	PIPE, 5" SCH. 10 X 6.88 LG.	1
39	FURNISHED	2" Y PATTERN MANUAL VALVE, EDEN BC-02146-8131	1
38	COML	PIPE, 5" SCH. 10 X 6.38 LG.	1
37	COML	PIPE, 5" SCH. 10 X 5.00 LG.	1
36	COML	ELBOW, 90°, LONG RADIUS, 2" SCH. 10	1
35	FURNISHED	FLEX HOSE, 1" IPS ENDS X 6.00 LG.	4
34	COML	PIPE, 1" SCH. 10 X 1.88 LG.	1
33	FURNISHED	FLEX HOSE, 1" IPS ENDS X 15.00 LG.	2
32	COML	TUBING, 6" O.D. X .065 WALL X 17.00 LG.	1
31	COML	ELBOW, 90° LONG RADIUS, 1" SCH. 10	4
30	MB-486096	ELBOW, 90° LONG RADIUS, 2" SCH. 10 MODIFIED	1
29	COML	PIPE, 2" SCH. 10 X 31.88 LG.	1
28	COML	PIPE, 1" SCH. 10 X 24.12 LG.	1
27	FURNISHED	FLEX HOSE, 5" IPS ENDS X 20.00 LG.	1
26	FURNISHED	FLEX HOSE, 2" IPS ENDS X 16.00 LG.	4
25	FURNISHED	FLEX HOSE, 1" IPS ENDS X 15.00 LG.	2
24	COML	PIPE, 2" SCH. 10 X 4.13 LG.	1
23	COML	PIPE, 1" SCH. 10 X 7.88 LG.	1
22	COML	ELBOW, 90°, SHORT RADIUS, 2" SCH. 10	1
21	COML	ELBOW, 90°, SHORT RADIUS, 1" SCH. 10	1
20	COML	HEX HEAD NUT, 5/16-18 UNC	20
19	COML	HHCS, 5/16-18 UNC X 2.25 LG.	20
18	MC-486090	8" MDC DEL-SEAL CF FLANGE, MODIFIED	1
17	COML	GASKET, COPPER, 6.01 O.D., MDC P/N 191017	1
16	EXISTING	6" FLANGED PORT "A" LAPD VESSEL	1
15	COML	PIPE, 2" SCH. 10 X 26.50 LG.	1
14	COML	PIPE, 1" SCH. 10 X 32.75 LG.	1
13	COML	PIPE CAP, 3" SCH. 10	3
12	COML	TEE, STRAIGHT, 3" SCH. 10	3
11	COML	PIPE, 3" SCH. 10 X 4.75 LG.	1
10	FURNISHED	1" Y PATTERN MANUAL VALVE, EDEN BC-02146-8122	2
9	FURNISHED	FLEX HOSE, 3" IPS ENDS X 20.00 OAL	1
8	COML	REDUCER, CONCENTRIC, 5" X 3" SCH. 10	1
7	COML	TEE, STRAIGHT, 5" SCH. 10	5
6	COML	SUPER INSULATION, 20-LAYERS	AS REQD.
5	MB-486088	TUBING, 6" O.D. X .065 WALL X 8.00 LG. (45°)	1
4	MB-486087	BLANK-OFF FLANGE 1" X 2" X 5" PIPE	1
3	COML	PIPE, 5" SCH. 10 X 22.75 LG.	1
2	MB-486086	FLANGE, CF, 2-3/4" O.D. X 1" PIPE	1
1	ME-466642	LAPD CONDENSER ASSEMBLY	1

PARTS LIST

A NOTE:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. THERE ARE APPROX. 110 WELDS.

*SPECIAL NOTES:
1. THE 3" FLEX HOSES (ITEMS 9 & 61) SHOULD BE RESTRAINED BY THREE Ø3/8" THREADED RODS.
2. THE 5" & 6" FLEX HOSES (ITEMS 27) & 88) SHOULD BE RESTRAINED BY THREE Ø1/2" THREADED RODS.

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	T.TOPE	17-JUN-2010
.XX	.XXX	ANGLES	DRAWN	W.CYKO	17-JUN-2010
± .03	± -----	±-----	CHECKED	J.RAUCH	15-JUL-2010
			APPROVED	T.TOPE	15-JUL-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL: SEE PARTS LIST ABOVE

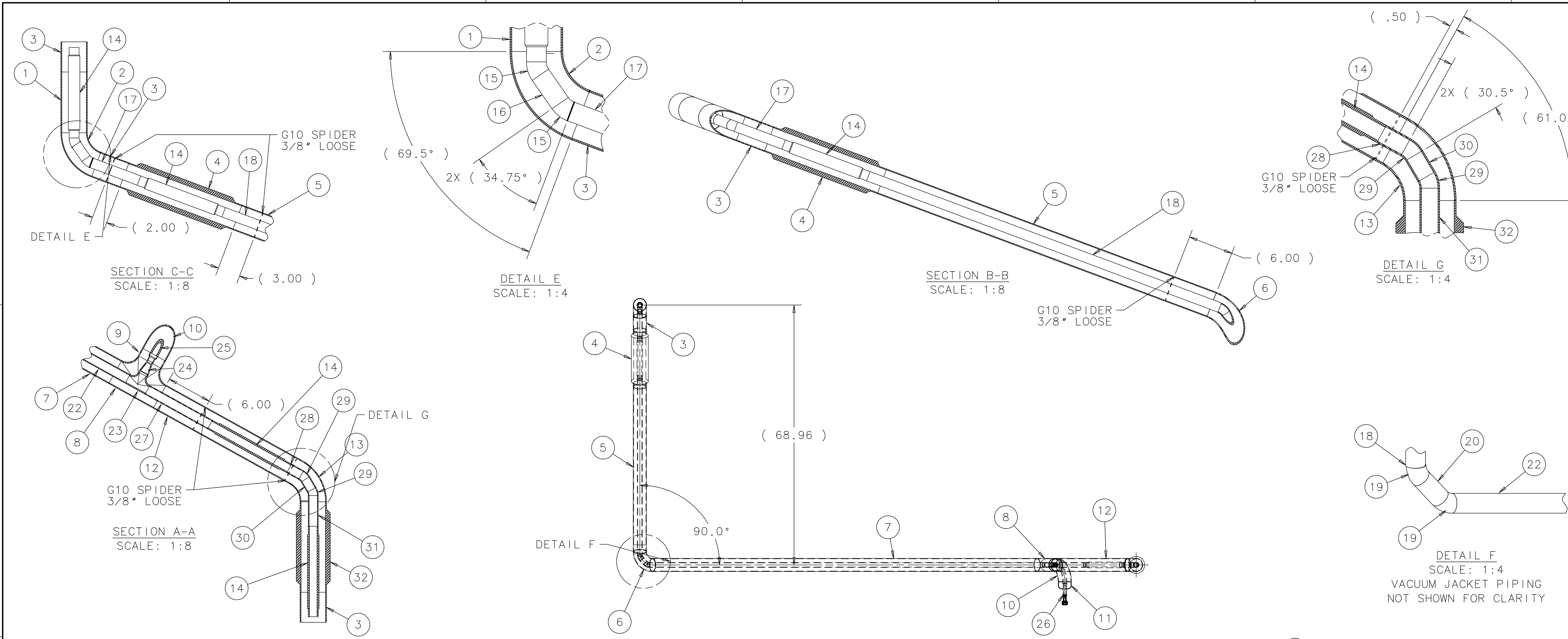
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

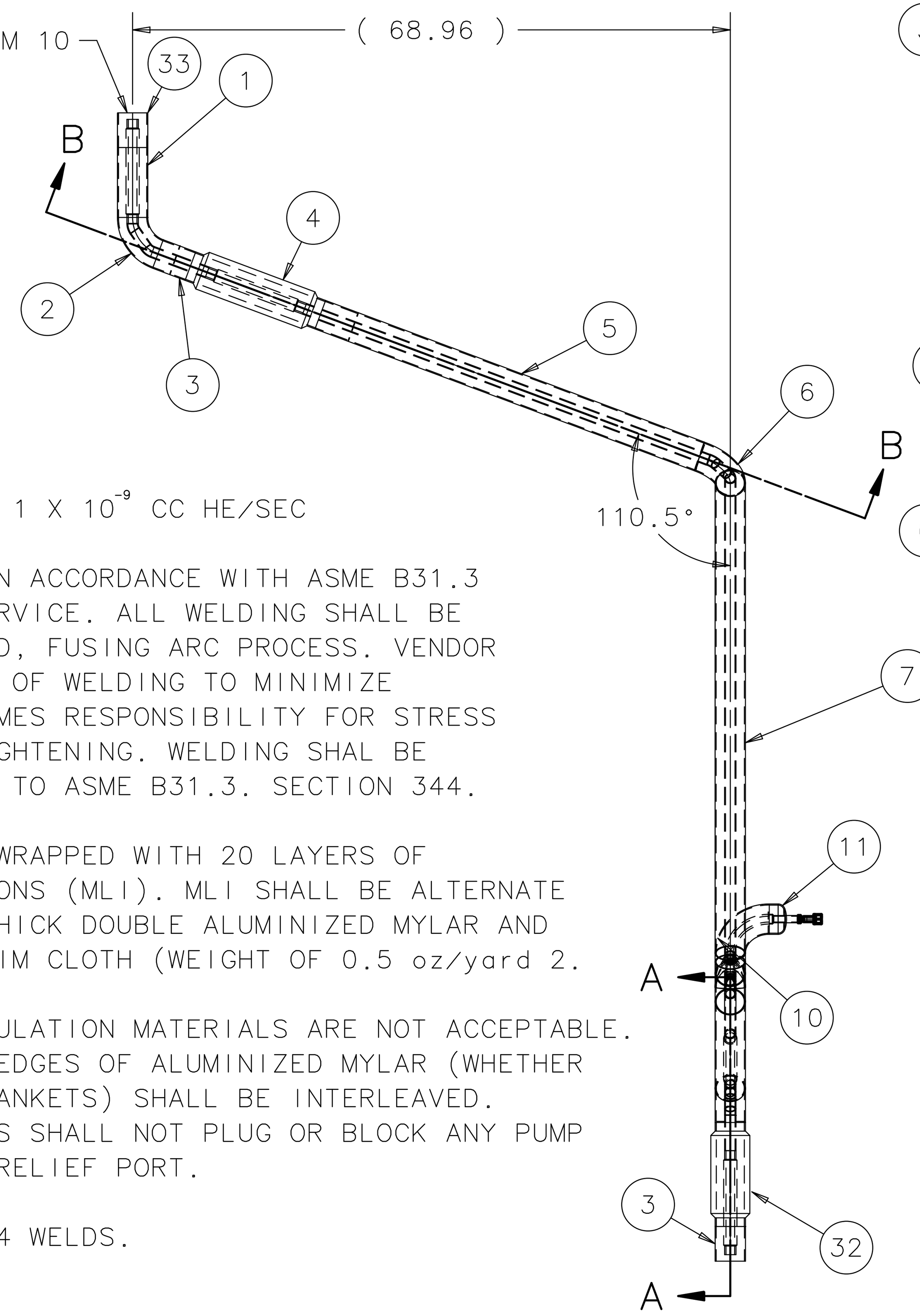
FLARE-MECHANICAL CRYOGENIC LAPD TANK CRYO PIPING PHASE 2

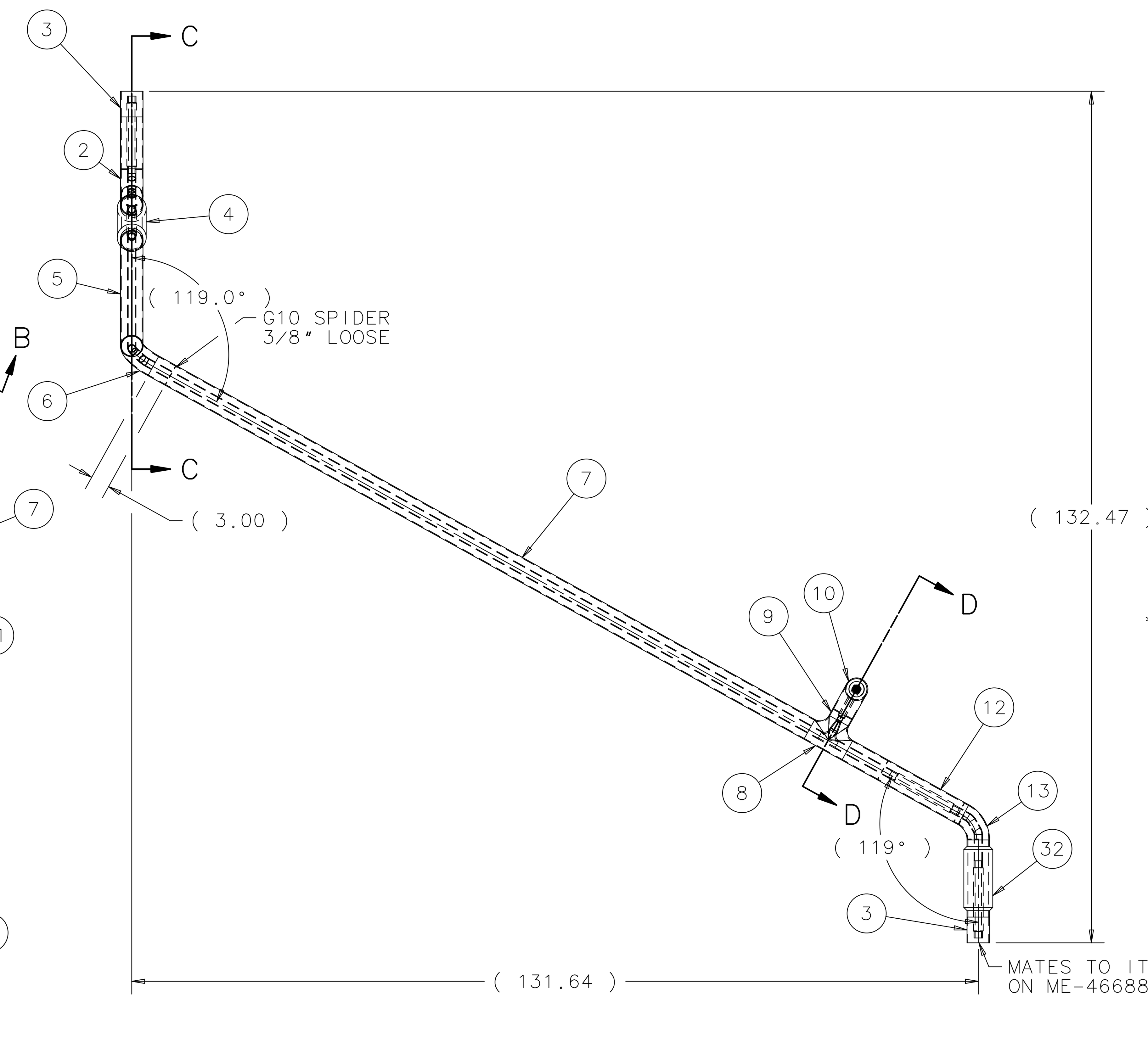
SCALE	DRAWING NUMBER	SHEET	REV
1:8 & AS NOTED	3942.320-ME-486029	1 OF 1	A

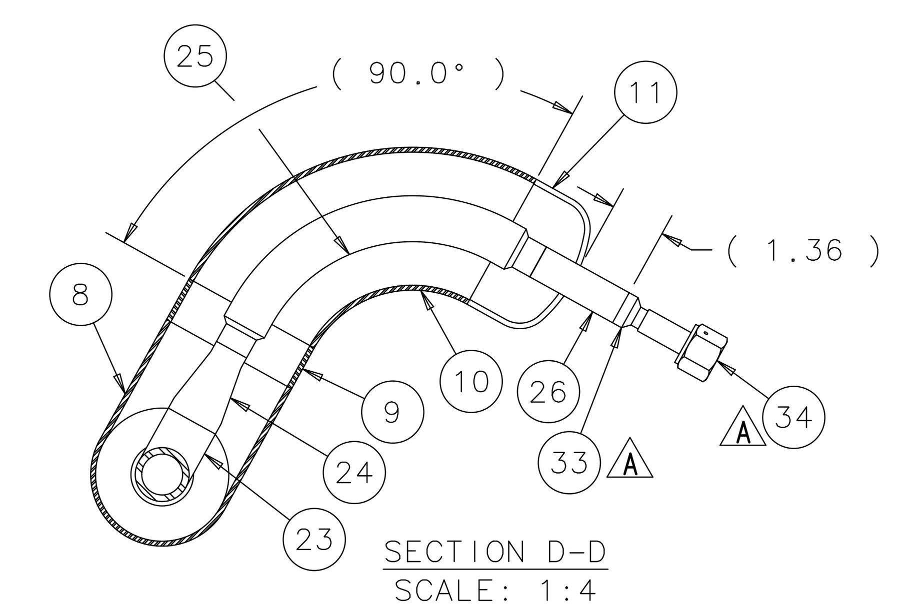
CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	ADDED ITEMS 33 & 34 & NOTES	J. TILLMAN	12-JAN-2011
		T. TOPE	20-JAN-2011









NOTES: A

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC
2. WELD ARGON PIPING IN ACCORDANCE WITH ASME B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSING ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHAL BE INSPECTED ACCORDING TO ASME B31.3. SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATIONS (MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM CLOTH (WEIGHT OF 0.5 oz/yard 2.

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. THERE ARE APPROX. 24 WELDS.

*SPECIAL NOTE: THE 3" X 16" FLEX HOSES (ITEM 4) SHOULD BE RESTRAINED BY THREE Ø3/8" THREADED RODS.

PARTS LIST

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
34 A	COML	VCR CONC. FEMALE 1/2" O.D. TUBE	1
33 A	MB-486152	ADPTR, 1/2" PIPE X 1/2" O.D. TUBE	1
32	COML	FLEX HOSE 3" IPS ENDS X 12.00 OAL	1
31	COML	PIPE, 1" SCH 10 X 4.07; 304SS	1
30	COML	PIPE, 1" SCH 10 X 1.63; 304SS	1
29	MB-486286	ELBOW, 1" SCH 10 LR; 30.5° MITER	2
28	COML	PIPE, 1" SCH 10 X 1.82; 304SS	1
27	COML	PIPE, 1" SCH 10 X 9.50; 304SS	1
26	COML	PIPE, 1/2" SCH 10 X 2.31; 304SS	1
25	COML	FLEX HOSE, 1/2" IPS ENDS X 9.25 OAL	1
24	COML	RED. CONC.; 1 X 1/2 SCH 10 304SS	1
23	COML	TEE, STRAIGHT, 1" SCH 10; 304SS	1
22	COML	PIPE, 1" SCH 10 X 119.60; 304SS	1
21		NOT USED	
20	COML	PIPE, 1" SCH 10 X 2.19; 304SS	1
19	MB-486289	ELBOW, 1" SCH 10 LR; 40° MITER	2
18	MB-486290	PIPE, 1" SCH 10 X 49.75; MITER	1
17	COML	PIPE, 1" SCH 10 X 6.75; 304SS	1
16	COML	PIPE, 1" SCH 10 X 2.29; 304SS	1
15	MB-486287	ELBOW, 1" SCH 10 LR; 34.75° MITER	2
14	COML	FLEX HOSE 1" IPS ENDS X 12.00 OAL	4
13	MB-486291	ELBOW, 3" SCH 10 LR; 61° MITER	1
12	COML	PIPE, 3" SCH 10 X 20.63; 304SS	1
11	MB-486084-3	PIPE CAP, 3" SCH 10 X1" IPS	1
10	COML	ELBOW, 3" SCH 10 LR; 304SS	1
9	COML	PIPE, 3" SCH 10 X 1.14; 304SS	1
8	COML	TEE, STRAIGHT, 3" SCH 10; 304SS	1
7	COML	PIPE, 3" SCH 10 X 116.63; 304SS	1
6	MB-486293	ELBOW, 3" SCH 10 LR; 80° MITER	1
5	MB-486294	PIPE, 3 SCH10 X 46.75; MITER	1
4	COML	FLEX HOSE 3" IPS ENDS X 16.00 OAL	1
3	COML	PIPE, 3" SCH 10 X 4.00; 304SS	3
2	MB-486292	ELBOW, 3" SCH 10 LR; 69.5° MITER	1
1	COML	PIPE, 3" SCH 10 X 8.06; 304SS	1

UNLESS OTHERWISE SPECIFIED					
.XX ± .03	.XXX ± ---	ANGLES ± ---	ORIGINATOR	T.TOPE	06-JAN-2011
			DRAWN	J.TILLMAN	06-JAN-2011
			CHECKED	W.CYKO	11-NOV-2010
			APPROVED	T.TOPE	12-NOV-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL: SEE PARTS LIST ABOVE

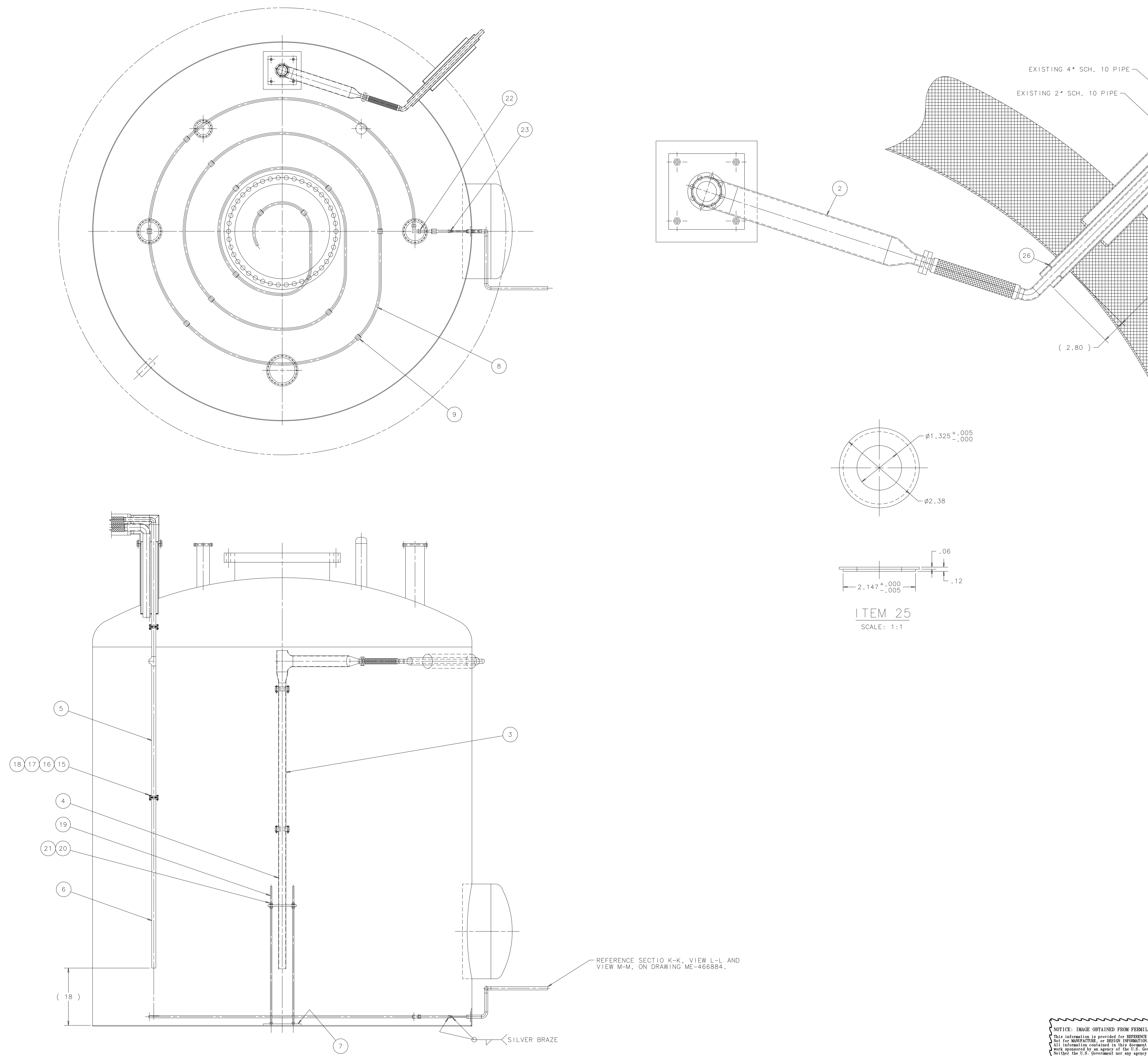
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE-MECHANICAL CRYOGENIC LAPD PHASE CONC. PIPING ASSY

SCALE	DRAWING NUMBER	SHEET	REV
1:32 & NOTED	3942.330-MD-486285	1 OF 1	A

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	DELETED PHASE SEPERATOR A	B.CYKO	14 DEC 2010
		T.TOPE	14 DEC 2010



ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
26 (A)	COML	SPIDER, STAINLESS STEEL	1
25 (A)	COML	SEAL-OFF PLATE (SEE DRAWING)	1
24 (A)	COML	TUBING, 5/8 NOM. (3/4 OD) X .035 WALL X 9.75 LG.	1
23 (A)	COML	BRAZE-TYTE REDUCER UNION 3/4 X 1/2 O.D. TUBE, TRULY TUBULAR P/N 5FF-12-8	1
22	COML	COMPRESSION TUBE FITTING, 90°, 3/4", STN. STL., McMASTER-CARR P/N 52245K641	1
21	COML	HEX NUT, STD., 1/2-13 UNC, S.S. 304	12
20	COML	FLAT WASHER, 1/2 NOM., S.S. 304	12
19	COML	THREADED ROD, CONTINUOUS, 1/2-13 UNC X 44.00 LG., McMASTER-CARR P/N 98920A033	4
18	COML	GASKET, COPPER, 1.53 I.D., DEL-SEAL P/N 191147	2
17	COML	HEX NUT, STD., 1/4-20 UNC, S.S. 304	12
16	COML	FLAT WASHER, 1/4 NOM., S.S. 304	24
15	COML	HHCS, 1/4-20 UNC X 1.50 LG., S.S. 304	12
14	COML	GASKET, COPPER, 2.51 I.D., DEL-SEAL P/N 191009	2
13	COML	HEX NUT, STD., 5/16-18 UNC, S.S. 304	16
12	COML	FLAT WASHER, 5/16 NOM., S.S. 304	32
11	COML	HHCS, 5/16-18 UNC X 2.00 LG., S.S. 304	16
10	MB-486195	PURGE LINE CRYO SPACER	2
9	MB-486196	PURGE TUBE SUPPORT	16
8	MC-486194	PURGE TUBE	1
7	MB-486199	PIPE SUPPORT BASE	1
6	MC-486206	VERTICAL 1" PIPING ASSY A	1
5	MC-486207	VERTICAL 1" PIPING ASSY B	1
4	MC-486202	VERTICAL PIPING ASSY D	1
3	MC-486203	VERTICAL PIPING ASSY A	1
2	MD-486219	PHASE SEPARATOR B	1
1 (A)		DELETED (NOT USED)	

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	T.TOPE	08-SEP-2010
± .03	± -----	± 1°	DRAWN	W.CYKO	08-SEP-2010
			CHECKED	T.TOPE	30-SEP-2010
			APPROVED	T.TOPE	30-SEP-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE

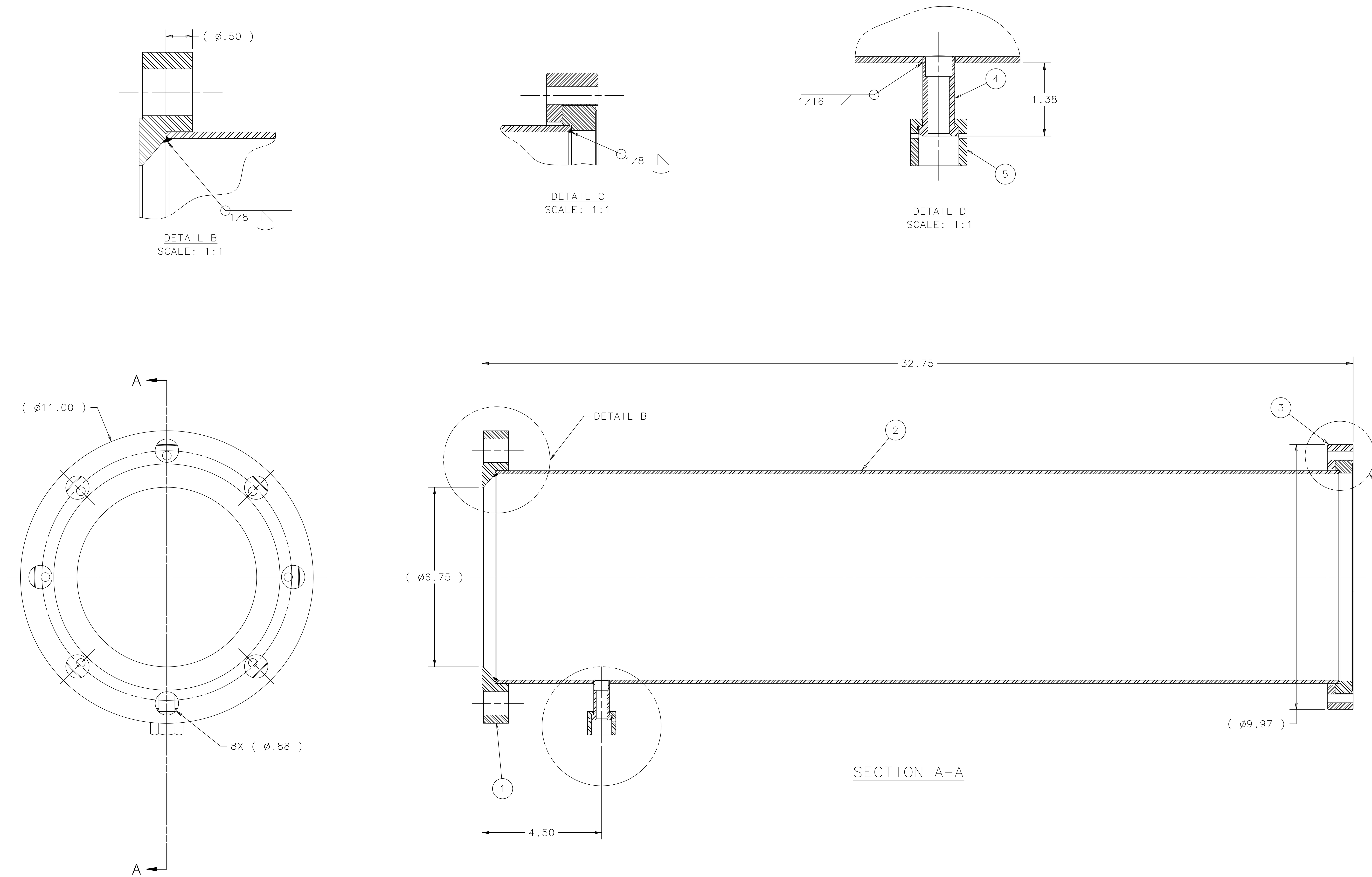
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

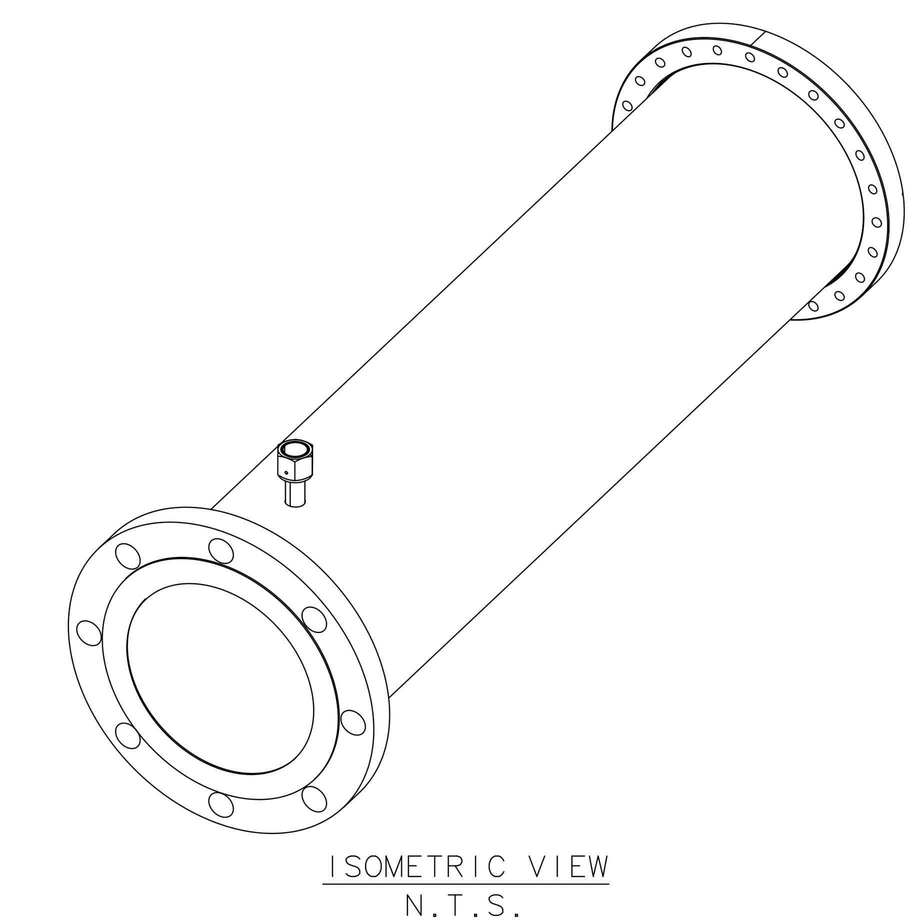
FLARE-MECHANICAL CRYOGENIC LAPD TANK PIPING ASSEMBLY

SCALE	DRAWING NUMBER	SHEET	REV
3:32 & AS NOTED	3942.320-ME-486227	1 OF 1	A

CREATED WITH : Ideas12NXSeries
GROUP: PPD/MECHANICAL DEPARTMENT

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE





ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
5	COML	1/2" VCR FACE SEAL FEMALE NUT SWAGELOK P/N: SS-8-VCR-1	1
4	COML	1/2" VCR X 1/2" TUBE FACE SEAL SOCKET WELD; SWAGELOK P/N: SS-8-VCR-3	1
3	COML.	DEL-SEAL CF FLANGE; ROT. CLEAR. 10 OD, 8 ID - MDC 100033 OR EQ	1
2	MB-486932	LAPD RELIEF VALVE RISER TUBE	1
1	MB-486952	LAPD FLNG. 150 6" BLANK MOD. A	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	T.TOPE	03-MAR-2011
± .03	± ---	± ---	DRAWN	J.TILLMAN	03-MAR-2011
			CHECKED	J.RAUCH	10-MAR-2011
			APPROVED	T.TOPE	14-MAR-2011

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

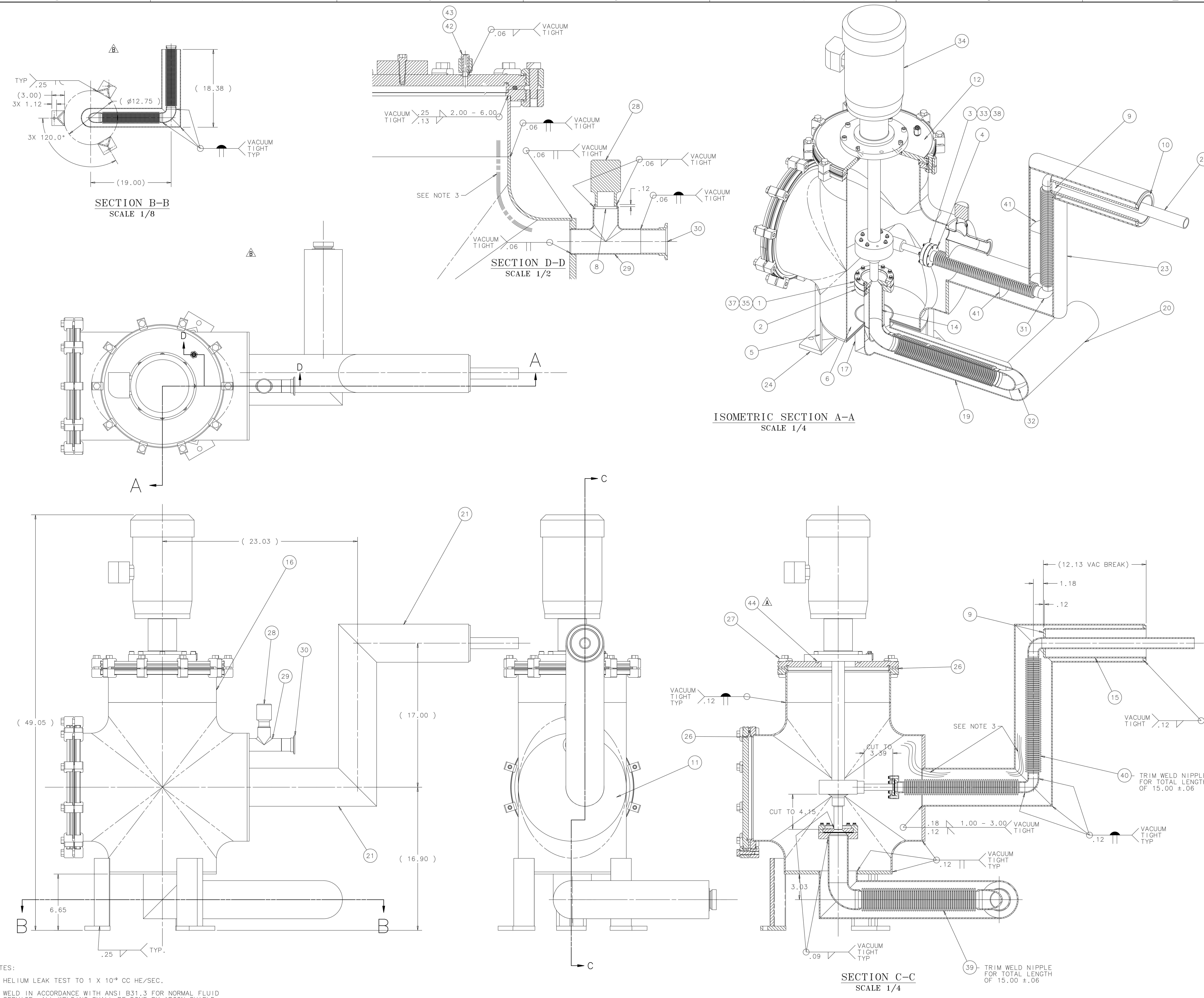
FLARE-MECHANICAL CRYOGENIC LAPD RELIEF VALVE RISER ASSY

SCALE	DRAWING NUMBER	SHEET	REV
1:2 & NOTED	3942.330-MD-486925	1 OF 1	

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

version 11.7.12 - page 76

NOTES:
1. ALL WELDS TO BE VACUUM LEAK TIGHT.
2. APPROXIMATE WEIGHT: 48 LBS



REV	DESCRIPTION	DRAWN / APPROVED	DATE / DATE
A	ADDED O-RING, ITEM #44	SAK	05-14-2010
		J.RAUCH	05-17-2010
B	ELIMINATED VAC BREAK ON INLET PIPING	J. TILLMAN	08-NOV-2010
		T. TOPE	15-NOV-2010

REV	ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
A	44		O-RING PARKER NO 2-433 VITON MASTER-CARR P/N 1201T241 OR EQUIV.	1
	43		VCR FEMALE NUT SWAGELOK P/N SS-4-VCR-1 OR EQUIV.	1
	42		VCR 1/4 TUBE GLAND, SOCKET WELD SWAGELOK P/N SS-4-VCR-3 OR EQUIV.	1
	41		SPIDER TO SUIT	A.R.
	40		1" INSIDE DIA BELLOWS, 1IPS 10SCH WELD NIPPLE, 15.00 TOTAL LG SINGLE BRAID, MASTER FLEX P/N AF4550	2
	39		2" INSIDE DIA BELLOWS, 2IPS 10SCH WELD NIPPLE, 15.00 TOTAL LG SINGLE BRAID, MASTER FLEX P/N AF4550	2
	38		12PT BOLT, SILVER PLATED .250-28UNF X 7/8 LG MDC P/N 190057 OR EQUIV.	6
	37		12PT BOLT, SILVER PLATED .312-24UNF X 1 1/4 LG MDC P/N 190058 OR EQUIV.	10
	36		O-RING PARKER NO 2-433, VITON MASTER-CARR P/N1201T241 OR EQUIV.	1
	35		GASKET, COPPER 1/4 HARD, 3.01 ID MDC P/N 191011 OR EQUIV.	1
	34		CRYOGENIC PUMP, LONG SHAFT, MAGNETIC DRIVE, WITH VARIBLE SPEED DRIVE, BARBER NICHOLS INC, P/N BNC-32B-000	1
	33		GASKET, COPPER 1/4 HARD, 1.45 ID MDC P/N 191004 OR EQUIV.	1
	32		90° ELBOW-SHORT RAD BUTT WELD 2IPS 10SCH, SS TYPE 304L	3
	31		90° ELBOW-SHORT RAD BUTT WELD 1IPS 10SCH, SS TYPE 304L	2
	30		HALF NIPPLE, NW-40-1 1/2 TUBE SIZE MDC P/N K150-LWS, 304 SS	1
	29		TEE, 1-1/2 TUBE X .065 WALL, 304 SS MDC P/N 404502 OR EQUIV.	1
	28		VACUUM PUMP OUT, 1.00 CVI ACME CRYOGENICS P/N V-1046-31	1
	27		CLAMP, DOUBLE CLAW, STEEL MDC P/N 802005 OR EQUIV	20
	26		CENTERING RING ASSEMBLY, VITON MDC P/N 810005 OR EQUIV.	2
	25		12IPS SCH10 BUTT WELD CROSS	1
	24	MC-466785	PLATE	3
	23	MC-466776	PIPE 4 SCH 10 X 21.44 LG MITER 2 S.S. 304	1
	22	MC-466774	PIPE 1 SCH 10 X 18 LG S.S. 304	1
	21	MC-466775	PIPE 4 SCH 10X15 3/8 LG MITER S.S. 304	2
	20	MC-466777	PIPE 4 SCH 10 X 19.00 LG MITER 2 S.S. 304	1
	19	MC-466778	PIPE 4 SCH 10 X 19.00 LG MITER 2-90 S.S. 304	1
B	18		NOT USED	
	17	MC-466780	PIPE 4 SCH10 MITER SHORT S.S. 304	1
	16	MC-466781	PIPE 12 SCH10 X 3.59 LG S.S. 304	1
B	15	MC-466784	PIPE 3 SCH10 X 12 LG S.S. 304	1
	14	MC-466783	PIPE 2 SCH10 X 5 9/16 LG S.S. 304	1
B	13		NOT USED	
	12	MC-466766	ISO LF NW320 MOD	1
	11	MC-466761	ADAPTER 12IPS - 4IPS 2 HOLES	1
B	10	MC-466764	ADAPTER RING 4IPS - 3IPS	1
	9	MC-466762	ADAPTER 3IPS - 1IPS	1
	8	MC-466759	ADAPTER 1.25ID - 1.400D	1
B	7		NOT USED	
	6	MC-466760	ADAPTER 12IPS - 4IPS	1
	5	MC-466765	ANGLE 2.5 X 1/4 X 8.00 LG	3
	4	MC-466770	CF ROT FLANGE 3/4TUBE MDC #100008	1
	3	MC-466773	CF FLANGE IPS 1 SCH10 MDC #130008	1
	2	MC-466772	CF FLANGE IPS 2 SCH10 MDC #130022	1
	1	MC-466769	CF ROT FLG 1" TUBE MDC #100022	1

PARTS LIST

NOTES:

1. HELIUM LEAK TEST TO 1 X 10^{-9} CC HE/SEC.
2. WELD IN ACCORDANCE WITH ANSI B31.3 FOR NORMAL FLUID SERVICE. ALL WELDING SHALL BE DONE BY ARGON SHIELD, FUSION ARC PROCESS. VENDOR DETERMINES SEQUENCE OF WELDING TO MINIMIZE DISTORTION AND ASSUMES RESPONSIBILITY FOR STRESS RELIEVING AND STRAIGHTENING. WELDING SHALL BE INSPECTED ACCORDING TO ANSI B31.3, SECTION 344.
3. ALL TUBING SHALL BE WRAPPED WITH 20 LAYERS OF MULTILAYER INSULATION(MLI). MLI SHALL BE ALTERNATE LAYERS OF 0.5 mil THICK, DOUBLE ALUMINIZED MYLAR AND WHITE POLYESTER SCRIM CLOTH (WEIGHT OF 0.5 oz./yard^2).

   BURNT OR SINGED INSULATION MATERIALS ARE NOT ACCEPTABLE. WHENEVER POSSIBLE, EDGES OF ALUMINIZED MYLAR (WHETHER INDIVIDUAL OR IN BLANKETS) SHALL BE INTERLEAVED. INSULATION MATERIALS SHALL NOT PLUG OR BLOCK ANY PUMP OUT PORT OR VACUUM RELIEF PORT.
4. EST WT 350 LBS

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	R.SCHMITT	22-JAN-2010
0.5°	.XXX	ANGLE	DRAWN	S.KINDELBERGER	01-MAR-2010
± .06	± .015	±0.5°	CHECKED	J.RAUCH	18-MAR-2010
			APPROVED	T.TOPE	18-MAR-2010

1. BREAK ALL SHARP EDGES .02 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 250
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

FLARE GENERAL PRELIMINARY DESIGN
LAPD ARGON PUMP CROSS VESSEL
ARGON PUMP VESSEL ASSEMBLY

SCALE	DRAWING NUMBER	SHEET	REV
1/8 & NOTED	3942.000-ME-466414	1 OF 1	B

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

Appendix C
In-Process weld inspection details

PPD Mechanical
In-Process Weld Inspection Form

(as per In-Process Weld Inspection Guidelines, AD Cryogenics, Nov 3, 2006)

Date_____________Project: ______________________________________
Pipe Section: ______________________ Weld Number:______________
Weld location: ____
Welder:____________________Inspector: ___________________________

<u>Before Welding:</u>

Type of weld: (butt)________ (other)___________
(1) Pipe #1 Size, Schedule and material: ________________________
(2) Pipe #2 Size, Schedule and material: ________________________

<u>(1) Joint Preparation and Cleanliness</u>

Joint Preparation and Cleanliness acceptable? ___________________

<u>(2) Welding Machine</u>

(a) Remote foot pedal? ___________
(b) DC straight machine? __________

<u>(3) Joint Fit-up, and Internal Alignment.</u>

(a) Internal alignment acceptable? ____________________
(b) Joint Clearance acceptable? _____________________
(c) End Preparation acceptable? _____________________

<u>(4) Filler Rod</u>

(a) AWS A5.9 stainless steel filler rod? ________________
(b) Filler rod: Class _______________ Diameter_____________

<u>(5) Purge Gas.</u>

(a) type of purge gas : __________________
(b) time length of purge: _________________ purge flow rate:________ SCFH___
(b) (if done) O2 reading: ___________O2 Monitor manf/model : ________

<u>(6) Inspection After Root Pass</u>

(a) No visible cracks. _____________
(b) No suck holes, which are small holes in middle of weld. ___________
(c) No porosity or obvious imperfections. ______________
(d) Filler material fused along edges of weld . __________

(8) Repeat inspection after every pass: ______________

(9) Final Inspection: ____________________

In-Process Weld Inspection Guidelines
PPD Mechanical Department
(As per AD Cryogenics Department
Nov. 3, 2006)

This procedure is only valid for: GTAW welding of 304SS, 304LSS, 316SS pipe, tube or pipe components such as valves by Fermilab certified welders.

Fermilab welders are certified to weld in any position so there is no need to verify the position when welding. An In-process weld inspection must reflect the WPS for an individual welder.

(1) Joint Preparation and Cleanliness.

Internal and external surfaces to be welded are to be clean and free from rust, oil, grease, dirt, paint, etc. Cleanliness is very important. Even dried residue from a coffee spill is unacceptable and can cause problems. Use scotch bright or Aluminum oxide to clean the joint. Do not use a carbon steel wire brush because it could leave carbon steel particles on the joint.

(2) Welding Machine

(a) Remote foot pedal required
(b) DC straight machine required

(3) Joint Fit-up, and Internal Alignment

(a) Internal Alignment:

Butt Weld: The inside surfaces of the two pieces being welded together must be aligned to within 1/32" of each other. If the two pieces are the same outside diameter and wall thickness, then this alignment can be confirmed by using a straight edge on the outside surface.

(b) Joint Clearance

Butt weld: the gap between the two pieces should be should be less than 1/16".
Socket weld: 1/16" clearance inside the socket.

(c) End Preparation

For butt welds where the wall thickness is over 3/32", prepare pipe ends as per Fig 328.4.2 (attached). If the wall thickness's of the two pipes or tubes differ, prepare their ends as per (attached) Fig 328.4.3.

(4) Filler material

(a) Certification

Filler rod must be AWS designation A5.9 (for stainless).

(b) Record diameter and class (308SS or 304LSS ... etc) of filler rod

(c) Required Filler Rod Class

If connecting	304SS to 304SS	use 308 filler rod
If connecting	304SS to 304LSS	use 308L filler rod
If connecting	304LSS to 304LSS	use 308L filler rod
If connecting	316SS or 304 SS to 316SS	use 316 filler rod

For any other combination consult with the Fermilab weld shop.

(5) Purge Gas

(a) Purity

Purge gas must be 99.995% pure welding grade Argon. Boiloff gas from a liquid argon dewar is acceptable.

(b) Purge Flow

Purge gas must flow through the pipe past weld joint to remove oxygen. As a general rule the preweld purge should give 5-6 volume changes. The attached AWS Fig. 2 chart can be used to determine the required flow rate and length of time of the purge.

(c) Oxygen concentration

Oxygen concentration must be less than 1%. If available, use an oxygen monitor to measure the O2 concentration of the exhausting purge gas.

(7) Inspection after Root Pass

(a) No visible cracks

(b) No suck holes, which are small holes in middle of weld.

(c) No porosity or obvious imperfections

(d) Filler material fused along edges of weld to parent material. Ideally the weld should be concave.

(8) Repeat inspection #7 above after every pass

(9) Final Pass

Final pass should have a convex shape. Maximum buildup should be less than 1/16" above surface of pipe or tube.

Appendix D
Charpy Impact Testing Memo

Fermilab

Accelerator Division
Cryogenic Department
630.840.6858 (office)
630.840.4989 (fax)

Memorandum

To: Arkadiy Klebaner, Jay Theilacker, Alex Martinez, Bill Soyars, Brian DeGraff, Jerry Makara, Michael Geynisman

From: Michael White

Subject: Charpy Impact Testing for LN2 Piping

Date: April 13, 2010

Summary of Revision 1

The initial Charpy Impact Testing for LN2 Piping memorandum that was sent on December 29, 2009 contains a known error. The memorandum suggested that welding 316 or 316L with 308L filler metal was acceptable. However, welding 316 or 316L with 308L filler metal is a violation of the AD/Cryo weld procedure, which has now been attached as Appendix 3 to this memo for easy reference. The Charpy impact testing that was performed qualified the AD/Cryo weld procedure for 308L filler rod, but the procedure must be followed to remain within the qualification. All instances where 316 or 316L stainless steel was previously mentioned have been removed, since those materials require the use of 316 filler rod according to the AD/Cryo weld procedure.

It should also be noted that type 308L filler rod also qualifies as type 308, so it is acceptable to weld type 304 to type 304 stainless steel using 308L filler rod even though it is not explicitly specified in the AD/Cryo weld procedure. This memorandum will be updated again once Charpy impact testing data becomes available for welds made with type 316 filler rod using the AD/Cryo weld procedure.

Introduction

The Fermilab Environmental Health & Safety Manual (FESHM) Chapter 5032 stipulates that cryogenic piping must meet the requirements of ASME B31.3. At colder temperatures materials often become brittle and lose their toughness. ASME B31.3 has impact testing requirements that force the designer to ensure that the selected materials do not undergo a brittle transition while being cooled down to the design temperature. Fermilab has had extensive and successful experience with using austenitic stainless steels for cryogenic piping. This paper was written to demonstrate that all impact testing requirements are satisfied for the vast majority of LN2 piping components at Fermilab through one set of impact tests that were recently performed.

Mandatory Impact Testing

The ASME B31.3 code specifies impact testing instructions in Section 323 and in Table 323.2.2. The two types of stainless steel most commonly used at Fermilab for cryogenic piping are type 304 and type 304L, which are listed in Table A-1 as having a minimum design metal temperature (MDMT) of -425°F (19 K). Table 323.2.2 has two columns of requirements, with column A for materials above their MDMT and column B for materials below their MDMT. The temperature of LN2 at atmospheric pressure is 77 K and well above the MDMT, so the requirements of column B (which are pertinent to LHe piping) will be neglected here.

Column A of Table 323.2.2 is subdivided into two additional columns, with column (a) for the base metal and column (b) for the weld metal requirements. The four types of steel commonly used for cryogenic piping at Fermilab are all austenitic steel, so the appropriate requirements can be found in row 4. Cell A-4(a) specifies that if either (1) carbon content by analysis is > 0.1% or (2) material is not in solution heat treated condition then impact testing is required. Cell A-4(b) specifies that if the MDMT is less than -20°F then the weld metal deposits must be impact tested.

Cell A-4 has two notes, Note (3) and Note (6), which provide exemptions from impact testing. Note (3) only applies above -155°F and therefore is not applicable to LN2 piping. Note (6) exempts material from impact testing if the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in). The wall thickness requirements difficult to maintain even if thin-walled tubing or piping is used, since the 2.5 mm wall thickness is often exceeded in the flanges, coupling, and adapters.

One source for stainless steel material composition requirements is ASTM A269-08 "Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing", which can be found using links to published standards provided by the Fermilab library. There are various other ASTM standards for stainless steel pipe (such as A312, A358, etc.) but the material composition requirements should be uniform for all ASTM standards. ASTM A269-08 Table 1 specifies that the maximum carbon content is 0.08% for 304 stainless steel and 0.035% for 304L stainless steels.

Section 6 of ASTM A269-08 specifies that the both types of stainless steel must be furnished in solution annealed condition. ASME B31.3 Table A-1 lists all each of the both types of stainless steel as having the same P-No, Group-No, MDMT, and allowable stress regardless of whether it is tube or pipe form. The heat treatment of the tubes and pipes must be similar since the ASME B31.3 listed properties are the same. Therefore, the conditions of cell A-4(a) have been satisfied and impact testing is not required on the base metal when using 304 or 304L stainless steel for LN2 piping.

Cell A-4(b) mandates impact testing on weld metal at LN2 temperatures for 304 or 304L stainless steel if the wall thickness is greater than 2.5 mm. Note (2) applies to all cells in column (b) and states "Impact tests that meet the requirements of Table 323.3.2, which are performed as part of the weld procedure qualification, will satisfy all requirements of para. 323.2.2 and need not be repeated for production welds." This means that once the AD/Cryo welding procedure is qualified, no more impact testing is required as long as the weld procedure continues to be followed.

Weld Procedure Qualification

The requirements for impact testing are listed in Table 323.3.1. Since impact tests are only required on the welds, the test is governed by the requirements in column A, cells A-4 to A-7. Cell A-4 states that one impact test is required for each welding procedure, type of filler metal, and flux used. AD/cryo only has one weld procedure, does not use flux for welding, and uses AWS-E308L filler metal so only one test is required. The number of test pieces is dictated by Cell A-5 and Note (3). Note (3) states that the test piece must be large enough to obtain three specimens from the weld metal. Cell A-5(a) states that one test validates a range of thicknesses from T/2 to T+ 0.25". A test on 1" Sch 10 pipe (T=0.109") then would cover the range of 0.055" to 0.359". Almost all fittings and pipe used for LN2 piping at Fermilab fall in this thickness range or below. Cell A-5 states that tests do not need to be repeated as long as the material has the same P-number and Group-number. ASME Boiler Pressure Vessel Code (BPVC) IX QW-422 lists 304 and 304L stainless steels as P-No. 8 and Group-No. 2. Both types of stainless steel typically used by AD/Cryo for LN2 piping will be covered by one set of impact tests.

Cell A-6 gives directions for the orientation and location of the specimens, which will be covered further in the next section. Cell A-7 states that the fabricator (FNAL) is responsible for the ensuring the tests are completed.

Charpy Impact Test Results

FNAL does not have a Charpy impact test facility, so the work was contracted out to Westmoreland Mechanical Testing & Research, Inc (WMT&R) in Youngstown, PA. WMT&R is accredited by the American Association for Laboratory Accreditation (A2LA) to meet ASTM E23 standards for impact testing.

Two 3" long 1" Schedule 10 304 stainless steel pipes were butt welded and sent to WMT&R for impact testing. Impact test specimens were cut and machined by WMT&R. Verbal and written instructions were provided to WMT&R regarding the location and orientation of the specimens. The written instructions included with the welded pipe were the following:

Please follow the instructions from ASME B31.3 Table 323.3.1 on the location and orientation of Charpy Impact test specimens on pipe welds:

Across the weld, with notch in the weld metal; notch axis shall be normal to material surface, with one face of specimen <= 1.5 mm (1/16 in.) from the material surface

Please include the lateral expansion in the test results for all three specimens. ASME B31.3 defines the lateral expansion as:

The increase in width of the broken impact specimen over that of the unbroken specimen measured on the compression side, parallel to the line constituting the bottom of the V-notch

Should you have any questions please contact Mike White at 630-840-6858 or mjwhite@fnal.gov

The AD/Cryo In-Process Weld Inspection form used on the sample sent to WMT&R is included in Appendix 1. The WMT&R test results are included in Appendix 2. ASME B31.3 Table 323.3.5 requires steels with a P-No. of 8 to have at least 0.015" of lateral expansion and has no requirements for dissipated energy. The test results showed that the three specimens had lateral expansion in the range of 0.021"-0.029" at -320°F (77K). All requirements of the Charpy impact test were satisfied.

Conclusion

All Charpy impact testing requirements have been satisfied for using 304 and 304L piping components with 308L filler metal and a wall thickness of less than 0.359". The extensive and successful experience Fermilab has had with the materials listed above has been reinforced with successful Charpy impact testing. No further testing should be required for most LN2 piping assemblies fabricated by AD/Cryo as long as thickness requirements are met.

Appendix E
Pressure Test Documentation

Pressure tests associated with this amendment will be added to this appendix.

Fermilab

Date: 4/24/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 29 (44 psid to vacuum jacket) psig **Maximum Allowable Working Pressure** 25 (all components rated for at least 160 psid) psig

1.1 x 25 + 1.1x 14.7 – 14.7 = 28.97

Items to be Tested

LAPD pump suction piping between tank and valve AV-501-Ar. Piping will be plugged with an expanding plug inside the tank. See attached sketch. Section of interest is from the tank wall to MV-368-Ar. Other piping sections will be tested later at higher pressure.

Location of Test PC4 **Date and Time**

Hazards Involved

Entry into the confined space of the LAPD tank to install the expanding pipe plug.

Safety Precautions Taken

Obtain the appropriate confined space permit which includes monitoring the air inside of the tank.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

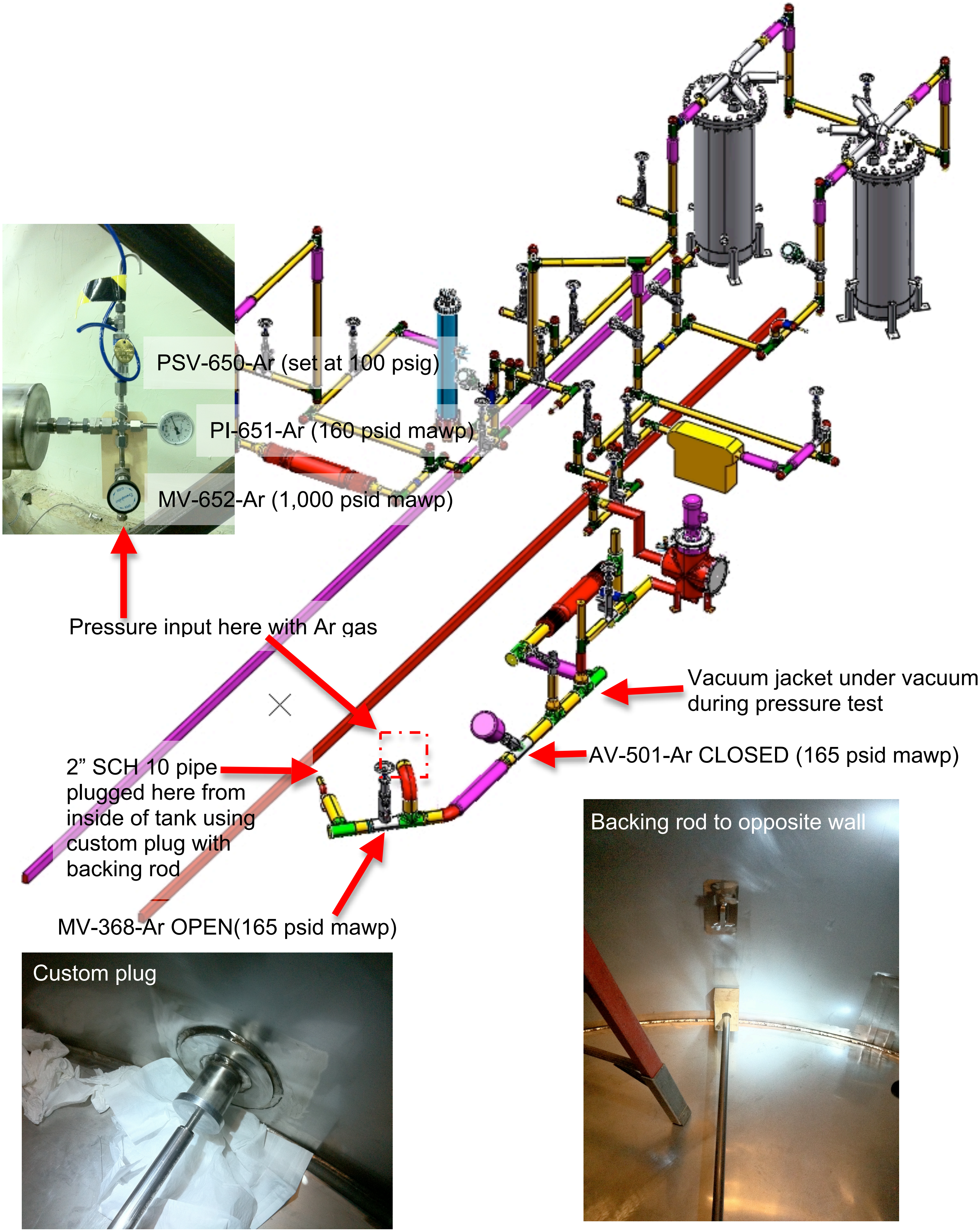
Division/Section Safety Officer 4-25-11
Dept/Date

Results

Vac jacket at 0.339 Torr @ test start
Vac jacket at 0.339 Torr @ test end
Held 29 psig at no leak for 10 min OK - TT.

Witness /SOTW **Dept/Date** 4-25-11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.


PSV-650-Ar (set at 100 psig)
PI-651-Ar (160 psid mawp)
MV-652-Ar (1,000 psid mawp)
Pressure input here with Ar gas
Vacuum jacket under vacuum during pressure test
AV-501-Ar CLOSED (165 psid mawp)
2" SCH 10 pipe plugged here from inside of tank using custom plug with backing rod
MV-368-Ar OPEN(165 psid mawp)
Custom plug
Backing rod to opposite wall

Fermilab

Date: 5/10/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 66 (80.7 psid to vacuum jacket psig **Maximum Allowable Working Pressure** 60 psig

Items to be Tested
LAPD condenser argon piping

Location of Test PC4 **Date and Time** 5/11/11 11:30 AM

Hazards Involved
Entry into the confined space of the LAPD tank to plug piping inside of the tank.
Stored energy of compressed gas.

Safety Precautions Taken
Obtain the appropriate confined space permit which includes monitoring the air inside of the tank.

Special Conditions or Requirements

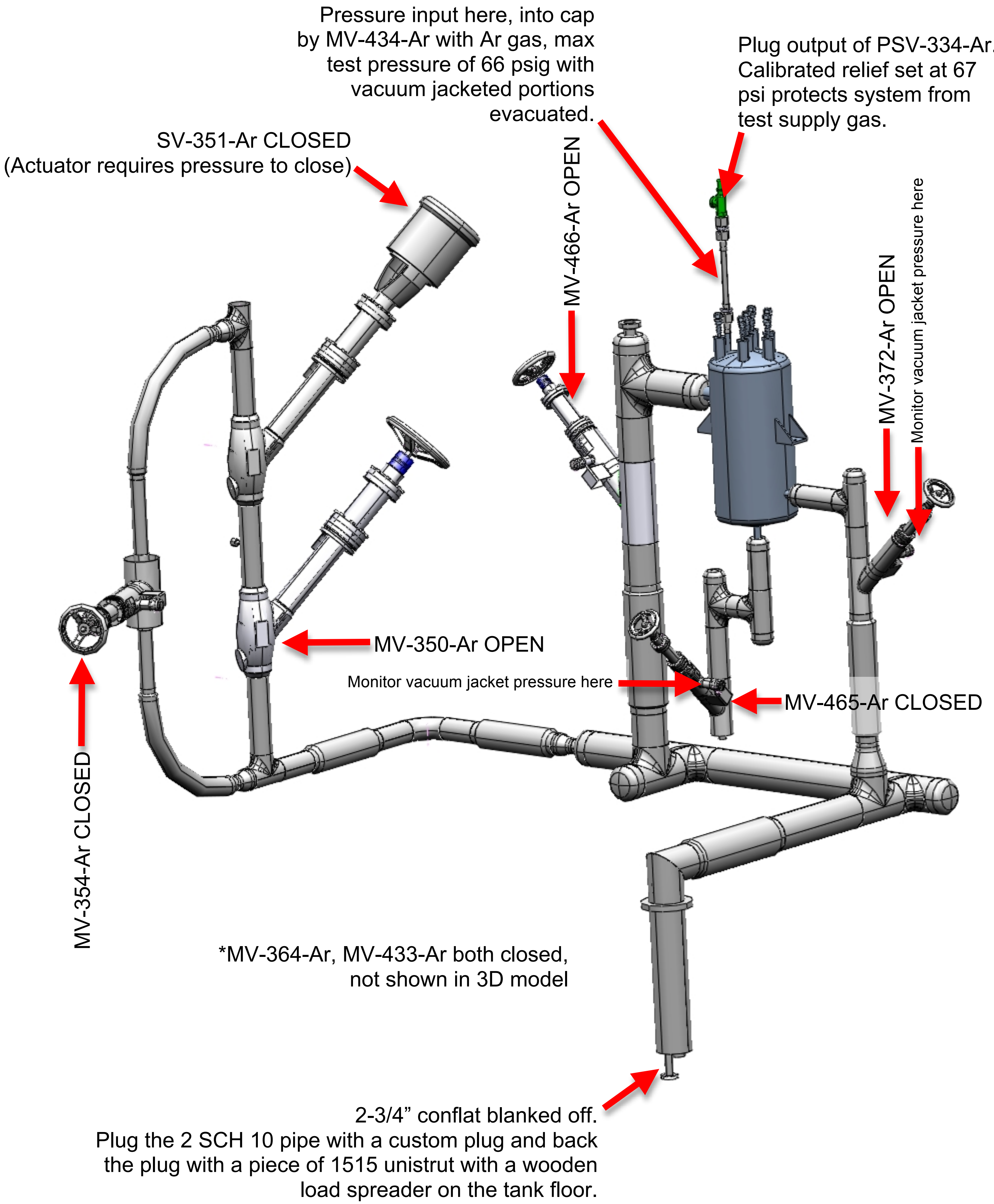
Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

Division/Section Safety Officer Rob Bushek
Dept/Date PD/ES&H 5-11-11

Results
Pump suction line vacuum @ .342 Torr, condenser vacuum at .116 Torr Before test
Both VJ's did not change during test
piping held 66 psig with no leak for 10 min - [signature] 13329N
no leak into VJ confirmed by vacuum readouts

Witness [signature] 15007N **Dept/Date** PD/ES&H 5-11-11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.


Pressure input here, into cap by MV-434-Ar with Ar gas, max test pressure of 66 psig with vacuum jacketed portions evacuated.
Plug output of PSV-334-Ar. Calibrated relief set at 67 psi protects system from test supply gas.
SV-351-Ar CLOSED (Actuator requires pressure to close)
MV-466-Ar OPEN
MV-372-Ar OPEN
Monitor vacuum jacket pressure here
MV-350-Ar OPEN
Monitor vacuum jacket pressure here
MV-465-Ar CLOSED
MV-354-Ar CLOSED
*MV-364-Ar, MV-433-Ar both closed, not shown in 3D model
2-3/4" conflat blanked off.
Plug the 2 SCH 10 pipe with a custom plug and back the plug with a piece of 1515 unistrut with a wooden load spreader on the tank floor.

Fermilab

Date: 4/28/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 111.5 psig (126.5 psid to vacuum jacket) **Maximum Allowable Working Pressure** 100 psig (115 psid, all components rated >=165 psid)

Items to be Tested
LAPD liquid return piping – see attached sketch for details.

Location of Test PC4 **Date and Time** 5/2/11 1:45PM

Hazards Involved
Entry into the confined space of the LAPD tank to check piping during test.

Safety Precautions Taken
Obtain the appropriate confined space permit which includes monitoring the air inside of the tank.

Special Conditions or Requirements

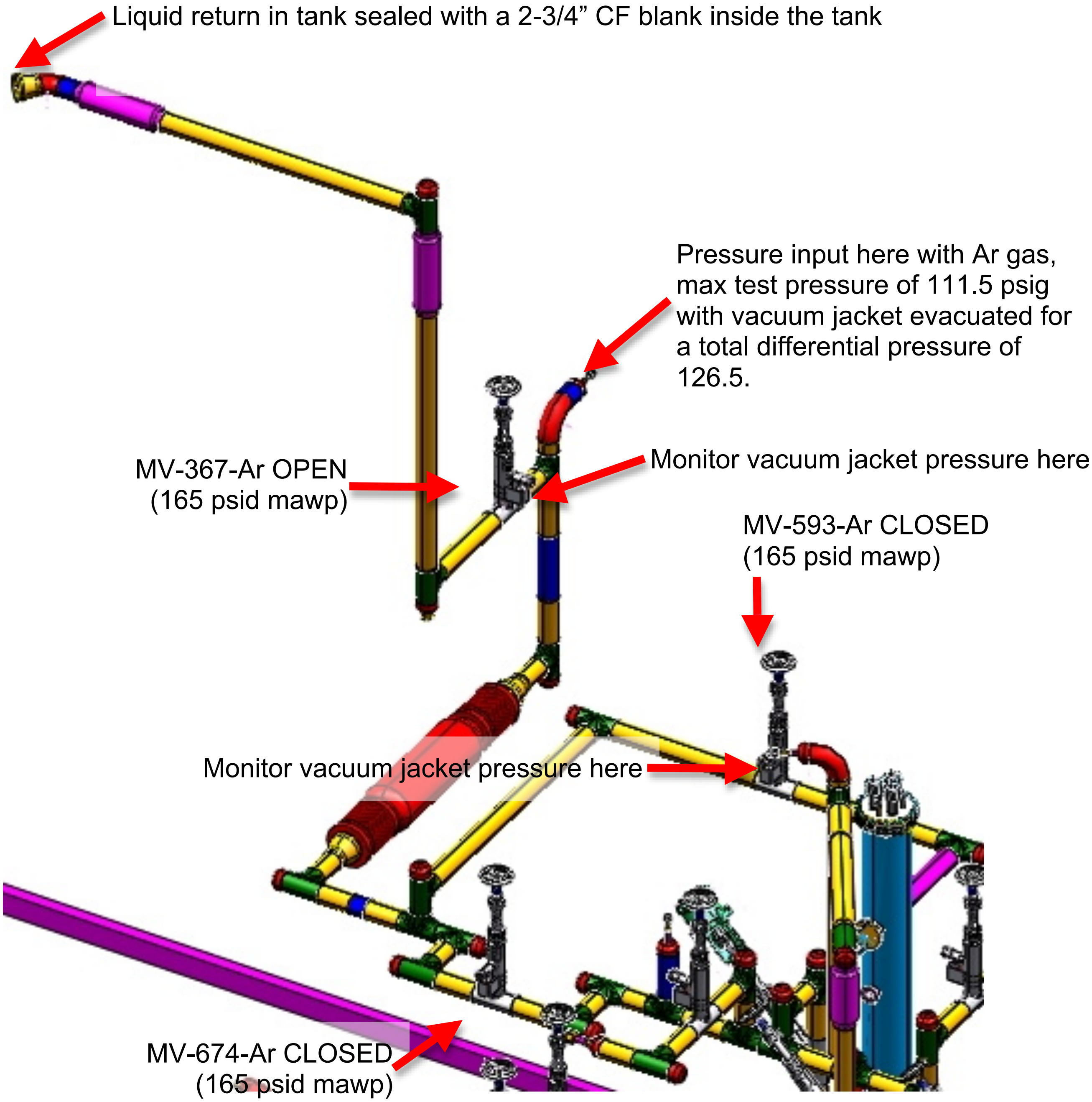
Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

Division/Section Safety Officer , 5007N
Dept/Date PD/ESH

Results
- tank side vacuum 0.148 Torr, purity monitor vacuum 0.037 Torr at test start
- tank side vacuum & purity monitor side vacuum unchanged after test
Pressure test was success no leakage for 10 min @ 111.5psig.

Witness (Safety Officer or Designee) **Dept/Date** PD/ESH / 5-2-11

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.


Liquid return in tank sealed with a 2-3/4" CF blank inside the tank
Pressure input here with Ar gas, max test pressure of 111.5 psig with vacuum jacket evacuated for a total differential pressure of 126.5.
MV-367-Ar OPEN (165 psid mawp)
Monitor vacuum jacket pressure here
MV-593-Ar CLOSED (165 psid mawp)
Monitor vacuum jacket pressure here
MV-674-Ar CLOSED (165 psid mawp)

Fermilab

Date: 5/12/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 110 psig **Maximum Allowable Working Pressure** 125 psig
Limited by pipe caps used for test

Items to be Tested
Two short sections of ¾" SCH 40 pipe welded to the LAPD tank differential pressure piping up to isolation valves MV-384-Ar and MV-330-Ar.
Both pieces of pipe are plugged inside with threaded pipe caps for the test.

Location of Test PC4 **Date and Time** 5.13.11

Hazards Involved
Entry into the confined space of the LAPD tank to check piping during test.

Safety Precautions Taken
Obtain the appropriate confined space permit which includes monitoring the air inside of the tank.

Special Conditions or Requirements

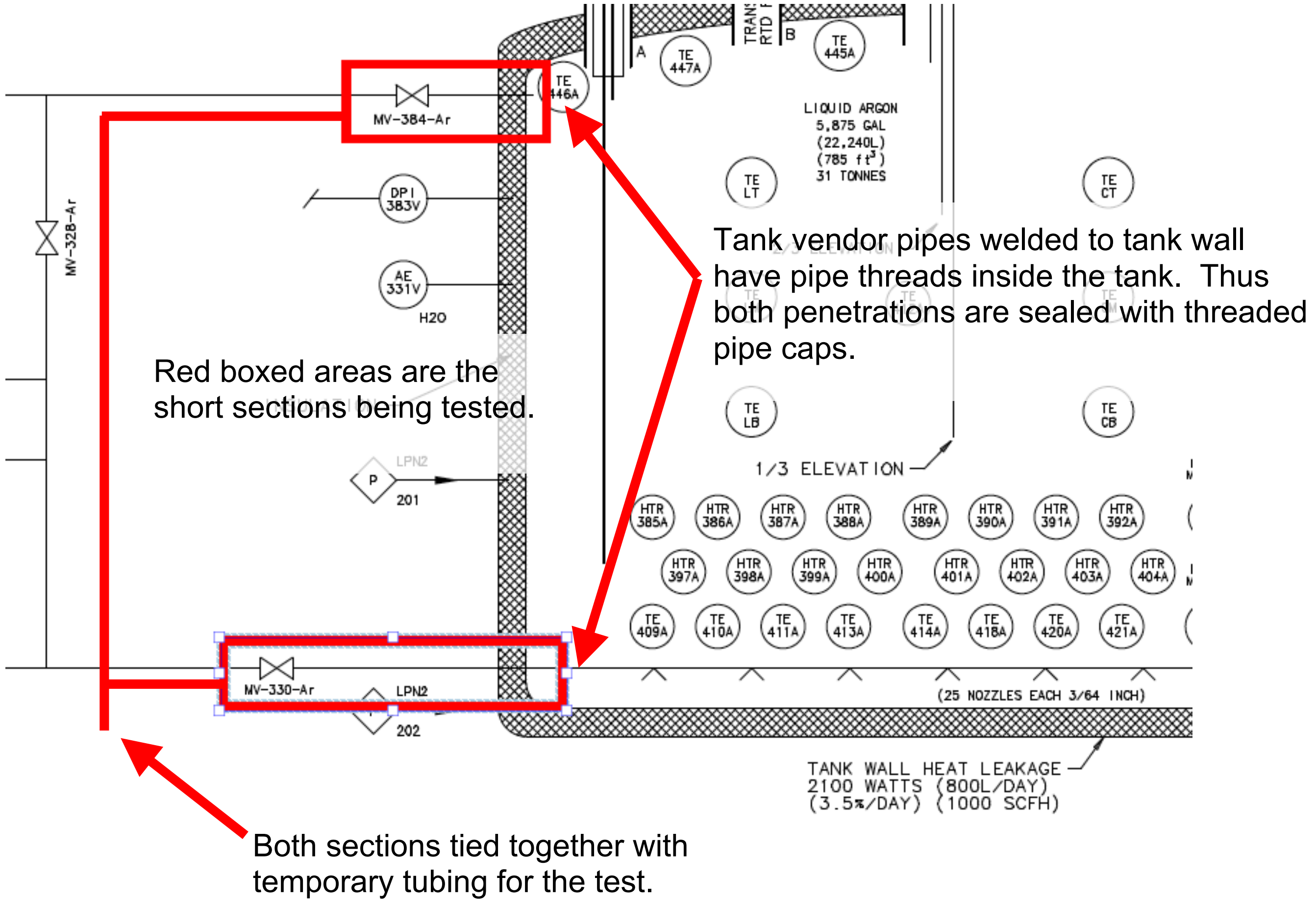
Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

Division/Section Safety Officer Ros Bosler
Dept/Date PD/ESH 5-13-11

Results
Held 110 psig for 10 minutes with no leakage. -Jim Jim

Witness (Safety Officer or Designee) **Dept/Date** PD/ESH 5-13-11

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.


MV-384-Ar
TE 446A
TE 447A
TE 445A
A
B
LIQUID ARGON
5,875 GAL
(22,240L)
(785 ft³)
31 TONNES
DPI 383V
AE 331V
H2O
MV-328-Ar
TE LT
TE CT
TE LB
TE CB
1/3 ELEVATION
P
LPN2
201
MV-330-Ar
LPN2
202
(25 NOZZLES EACH 3/64 INCH)
TANK WALL HEAT LEAKAGE
2100 WATTS (800L/DAY)
(3.5%/DAY) (1000 SCFH)
Tank vendor pipes welded to tank wall have pipe threads inside the tank. Thus both penetrations are sealed with threaded pipe caps.
Red boxed areas are the short sections being tested.
Both sections tied together with temporary tubing for the test.

Fermilab

Date: 2/8/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [X]Hydrostatic [] Pneumatic

Test Pressure < 3000 (To failure) psig **Maximum Allowable Working Pressure** Tbd psig

Items to be Tested
A fixed and a rotatable stainless steel 4.5" OD conflat flange pair welded to a seamless stainless steel 2" OD tube with a 0.120" wall. Tube ends are capped with 3/8" thick stainless plate welded to the 2" OD tube. A computer analysis of this conflat pair has been performed to establish a positive pressure rating for these flanges which are only rated for vacuum by the manufacturer. Despite only being rated for vacuum, these flanges are often used in internal pressure applications. To verify the computer analysis the flange pair will be hydraulically tested until leakage occurs. Several of these tests will occur over the next few weeks.

Location of Test PAB Calibration Shop **Date and Time** tbd 2/9/11

Hazards Involved
High pressure jet of water due to leakage from the flanges. The test will be performed hydraulically such that the stored energy is minimized. All components are stainless steel such that brittle failure will not occur.

Safety Precautions Taken
A translucent plastic panel will protect personnel from leaking water. Personnel will wear eye protection.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

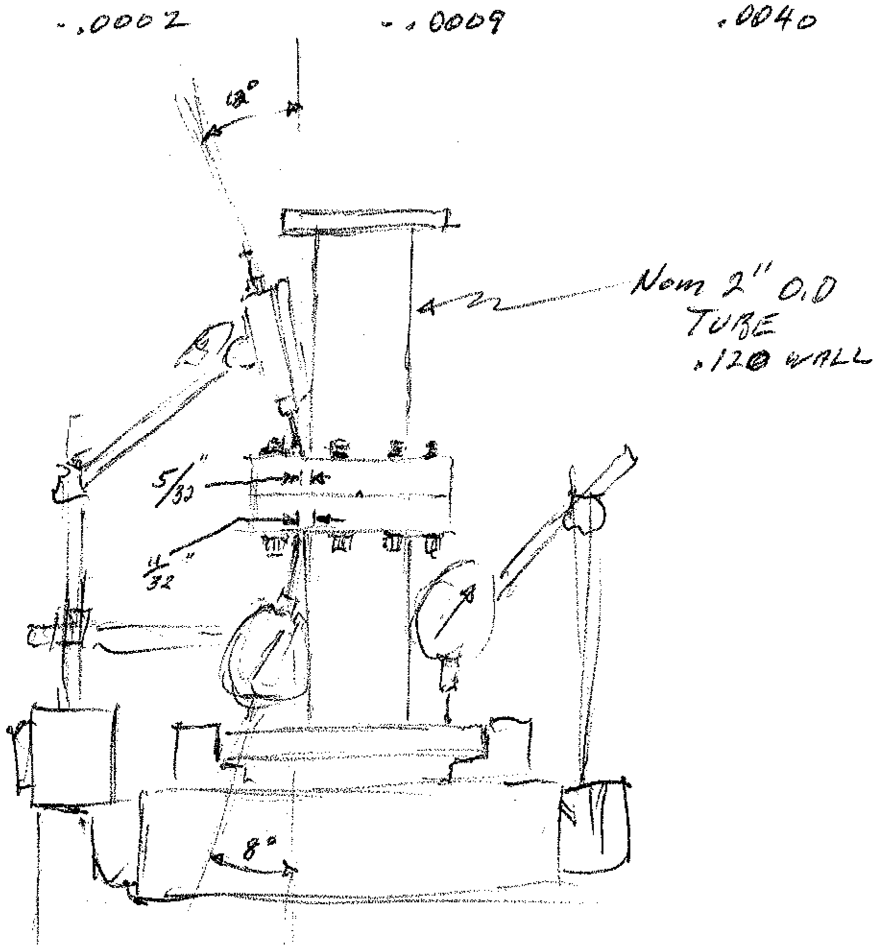
Division/Section Safety Officer Rob Bushek
Dept/Date ESH / 2-9-11

Results
Flange leaked at 2,600 psi
Botom flange -.002"
CF Fixed -.0012" } displacements
CF Rot .0054"

Witness 15007N **Dept/Date** 2-9-11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

Pressure	Bottom (BASE) Flange	FIXED FLANGE	ROTATABLE FLANGE	Notes
	INITIAL	8° 11/32"	12° 5/32"	
	0	0	0	
250	0	0	0	
500	0	0	0	
750	0	0	0	
1000	0	-.00025	.0005	
1250	0	-.0005	.001	
1500	-.0001	-.0006	.0012	
1750	-.0002	-.00075	.00[illegible]	
2000	-.0002	-.001	.0026	
2250	-.0002	-.001	.0034	Holding a minute before Reading.
2500	-.0002	-.0011	.0046	
2600	-.0002	-.0012	.0054	leaks
0	-.0002	-.0009	.0040	



Fermilab

Date: 2/8/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 375 psig **Maximum Allowable Working Pressure** tbd by test psig
100 psig desired

Items to be Tested
A Conax Technologies fiber optic feed thru welded to a 2-3/4" OD conflat. Conax Technologies rates the feed thru for 50 psig. Discussions with the vendor suggest that the 50 psig rating is based upon leakage around the fibers. The standard piping components from which the feed thru is constructed can take much higher pressures. According to the B31.3 piping code the pressure rating of components can be determined thru testing. B31.3 states ASME B16.9 is one method that can be used to determine the component pressure rating. For stainless steel components B16.9 requires a test at 3.75x the desired working pressure.

Location of Test PAB Calibration Shop **Date and Time** 2/9/11 1:30pm

Hazards Involved
Leakage of high pressure gas thru the fiber optic feed thru.

Safety Precautions Taken
Containment will be placed around the test piece. Personnel will wear ear protection and eye protection. Entry into the calibration shop will not be allowed during the test.

Special Conditions or Requirements

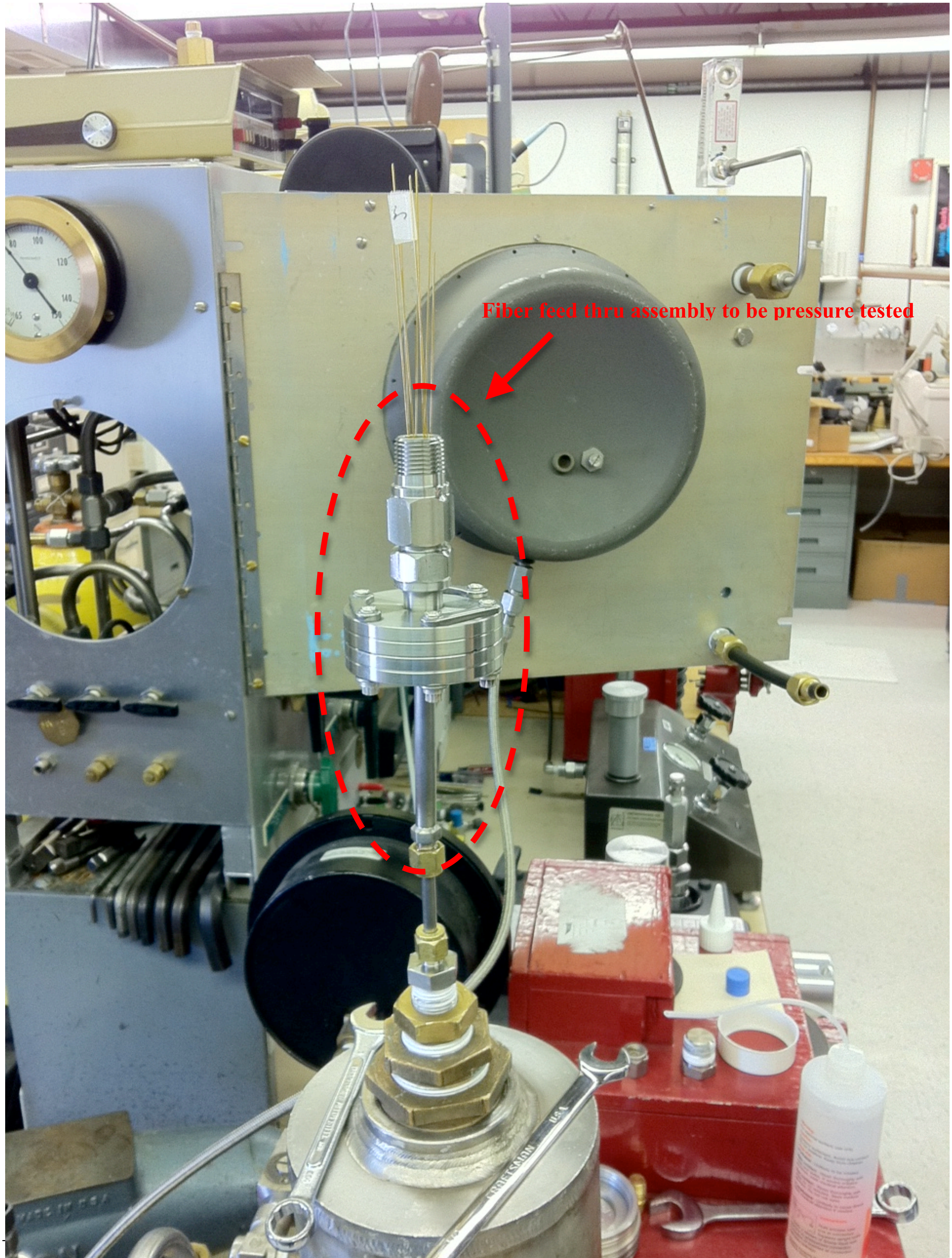
Qualified Person and Test Coordinator Terry Tope 2/9/11
Dept/Date PPD/MD/

Division/Section Safety Officer Kos Bushen
Dept/Date 2-9-11 ES&H

Results
Held 375 psig while the feed thru was covered in snoop, no visible bubbles for 10 min. Feed thru was filled with 3 optical fibers and ~~four~~ five feed thru pins

Witness 15007N **Dept/Date** ES&H 2-9-11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.


Fiber feed thru assembly to be pressure tested

2/9/11 Pneumatic Pressure Test of Fiber-Optic Feed through Assembly

Snoop filled cavity above feed through membrane.

50 psig	-	No	Bubbles
100 psig	-	No	Bubbles
150 psig	-	No	Bubbles
200 psig	-	"	"
250 psig	-	"	"
300 psig	-	"	"
350 psig	-	"	"
375 psig	-	"	"

Hold for 2 min.

Note. - three fibers used of eight holes. remaining five holes plugged with stepped pins.

Vent to atm.

RKB

Fermilab

Date: 4/11/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [X]Hydrostatic [] Pneumatic

Test Pressure 375 psig **Maximum Allowable Working Pressure** tbd by test (100 psig desired) psig

Items to be Tested
A conflat vacuum valve. It is desired to use a conflat flanged vacuum valve in a system that can be pressurized to 100 psig. The conflat valve can handle significant pressure based on its substantial construction but it is not rated for internal pressure. A pressure test to 375 psig will qualify it for use at 100 psig.

Location of Test PAB Calibration Shop **Date and Time** 4/11/11 1:30 PM

Hazards Involved
High pressure jet of water due to leakage from the flanges. The test will be performed hydraulically such that the stored energy is minimized. All components are stainless steel such that brittle failure will not occur.

Safety Precautions Taken
Personnel will wear eye protection.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

Division/Section Safety Officer
Dept/Date

Results
Held 375 psig without a leak for 10 + minutes - Terry Tope

Witness _____ 15000 Dept/Date 4-11-11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

Reference:
Mfr: Marsh Instruments
Type: 4" Test Gauge 0-600psig

Pressure Test Results Sheet
Test Item: vacuum valve
Mfr: Varian
Model: 951-5017

Revision: 2/25/2011 RKB
Test date: 4/11/11
Test range: 0-375 psig max.

Time	Pressure (psig)	Results Notes	Intitials
1340	0.0	Start test	RKB
1343	100.0	no leakage	RKB
1344	150.0	"	RKB
1345	200.0	"	RKB
1346	250.0	"	RKB
1348	320.0	"	RKB
1352	375.0	"	RKB
1400	375.0	hold for 8 minutes: no leakage	RKB
1401	0.0	end test	RKB

Fermilab

Date: 6/27/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 111.5 psig **Maximum Allowable Working Pressure** 100 psig
1.1 x (100 + 14.7) – 14.7 = 111.5 psig, 126.2 psid for vacuum jacketed portions

Items to be Tested
The lapd inline purity monitor vessel and associated piping and instrumentation as installed in PC4. See attached test schematic.

Location of Test PC4 **Date and Time** tbd 3pm 6/28/11

Hazards Involved
Stored energy of compressed gas.

Safety Precautions Taken
Personnel will wear eye protection.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

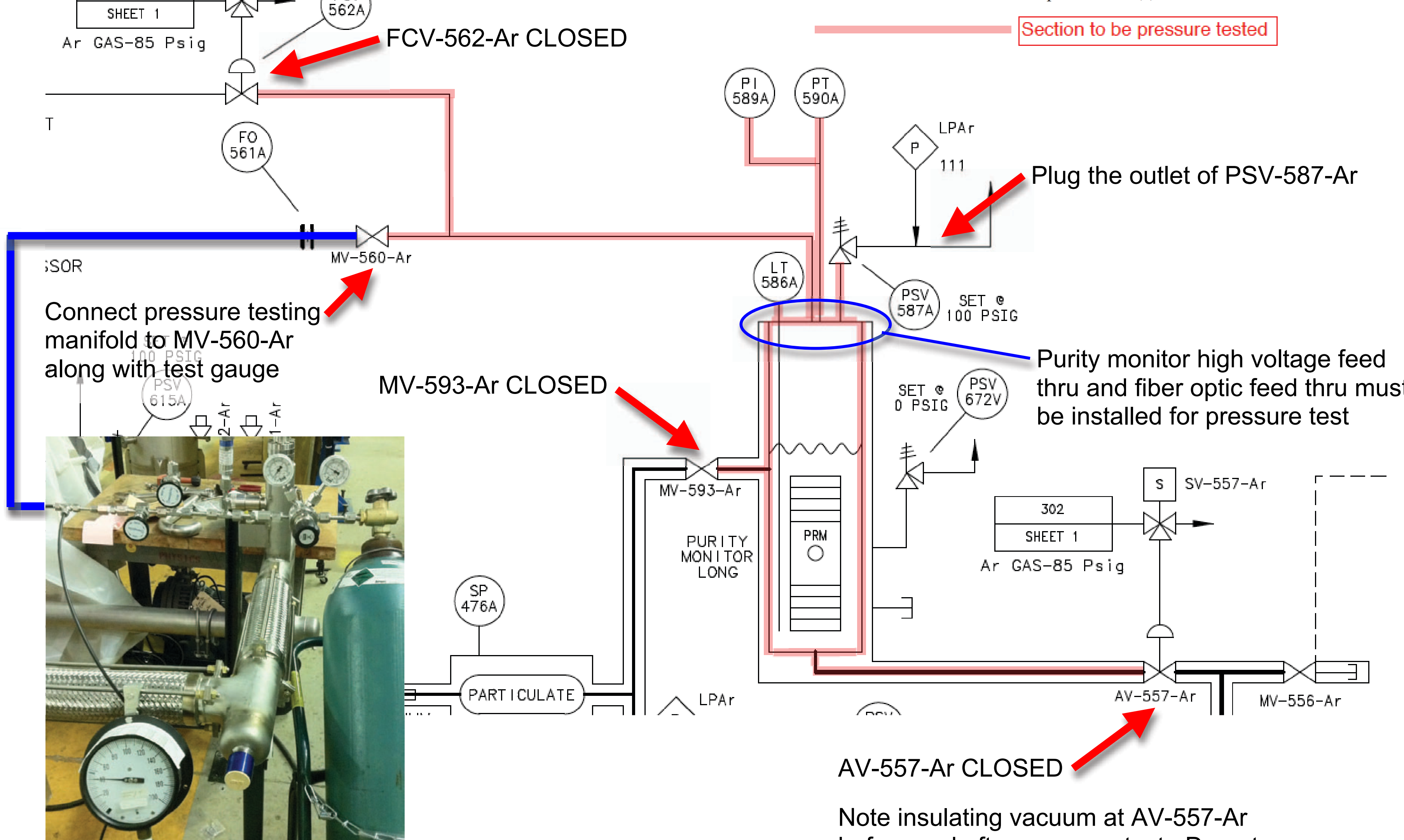
Division/Section Safety Officer Ros Bushek
Dept/Date PD/ESH 6-28-11

Results
VJ @ .067 Torr @ test start/ok at end
Held 112 psig for 10 min w/out pressure drop.
Relief valve outlet cap leaked, pressurized outlet side to keep relief from opening. PSV-587-Ar

Witness _______ **Dept/Date** PD/ESH 6-28-11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).



Note insulating vacuum at AV-557-Ar before and after pressure test. Do not vacuum pump insulating vacuum during the pressure test.

Fermilab

Date: 7/18/11

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 111.5 (126.5 psid to vacuum jacket) psig **Maximum Allowable Working Pressure** 100 (115 psid, all components rated >=150 psid) psig

Items to be Tested
LAPD purification piping – see attached sketch for details.

Location of Test PC4 **Date and Time** TBD

Hazards Involved
Stored energy of compressed gas

Safety Precautions Taken
Wear safety glasses.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope Terry Tope 13324N
Dept/Date PPD/MD/

Division/Section Safety Officer PD ES&H Eric McHugh
Dept/Date 7/18/11

Results Successful hold at test pressure for 10 mins.

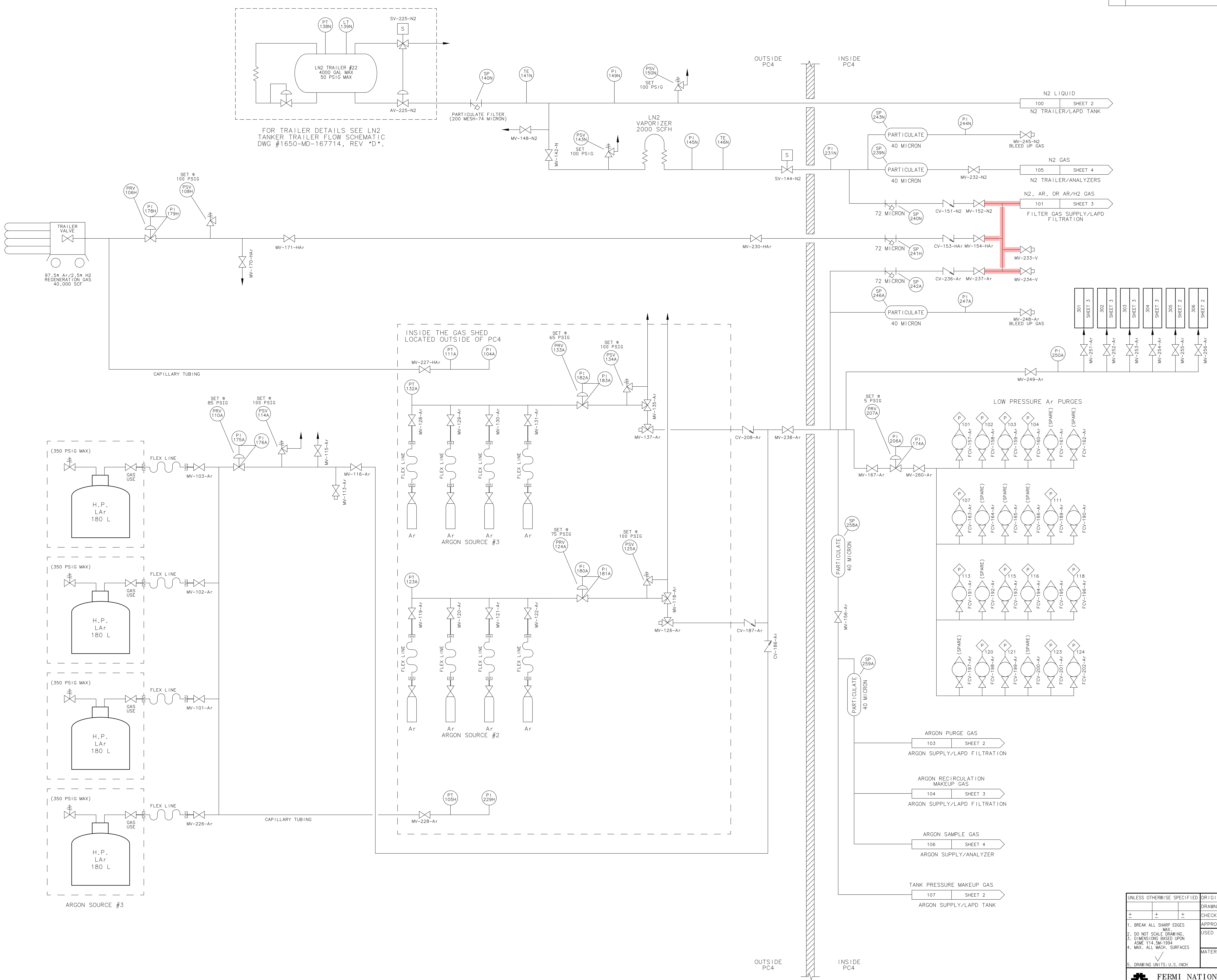
Witness 13747N **Dept/Date** 7.18.11
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

Highlighted sections to be pressure tested to 111.5 psig (126.5 psid for vacuum jacketed portions)

F	MISC. REVISIONS MADE.	J.CATALANELLO	26-FEB-2010
		M.ADAMOWSKI	26-FEB-2010
G	MISC. REVISIONS MADE.	J.CATALANELLO	10-JAN-2011
		T.TOPE	12-JAN-2012
H	MISC. REVISIONS MADE.	J.CATALANELLO	10-JAN-2011
		T.TOPE	03-FEB-2011
J	MISC. REVISIONS MADE.	J.CATALANELLO	23-FEB-2011
		T.TOPE	28-FEB-2011
K	MISC. REVISIONS MADE.	J.CATALANELLO	04-MAR-2011

REV	DESCRIPTION	DRAWN / APPROVED	DATE
A	ADDED TAG NUMBERS TO VALVE TYPES	V. MAJDANSKI	25FEB08
		R. SCHMITT	26FEB08
B	MOVE CONDENSOR OUTSIDE TANK	J.CATALANELLO	07-DEC-2008
		R.SCHMITT	10-DEC-2008
C	MISC. REVISIONS MADE.	J.CATALANELLO	23-DEC-2008
		R.SCHMITT	06-JAN-2009
D	MISC. REVISIONS MADE.	J.CATALANELLO	17-NOV-2009
		T.TOPE	14-DEC-2009
E	MISC. REVISIONS MADE.	J.CATALANELLO	17-NOV-2009
		T.TOPE	15-JAN-2010



UNLESS OTHERWISE SPECIFIED			ORIGINATOR	R.SCHMITT	26-JUN-2007
			DRAWN	J.CATALANELLO	07-DEC-2007
±	±	±	CHECKED	R.SCHMITT	12-DEC-2007
1. BREAK ALL SHARP EDGES MAX. 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ASME Y14.5M-1994 4. MAX. ALL MACH. SURFACES 5. DRAWING UNITS: U.S. INCH			APPROVED	R.SCHMITT	12-DEC-2007
			USED ON		
			MATERIAL		

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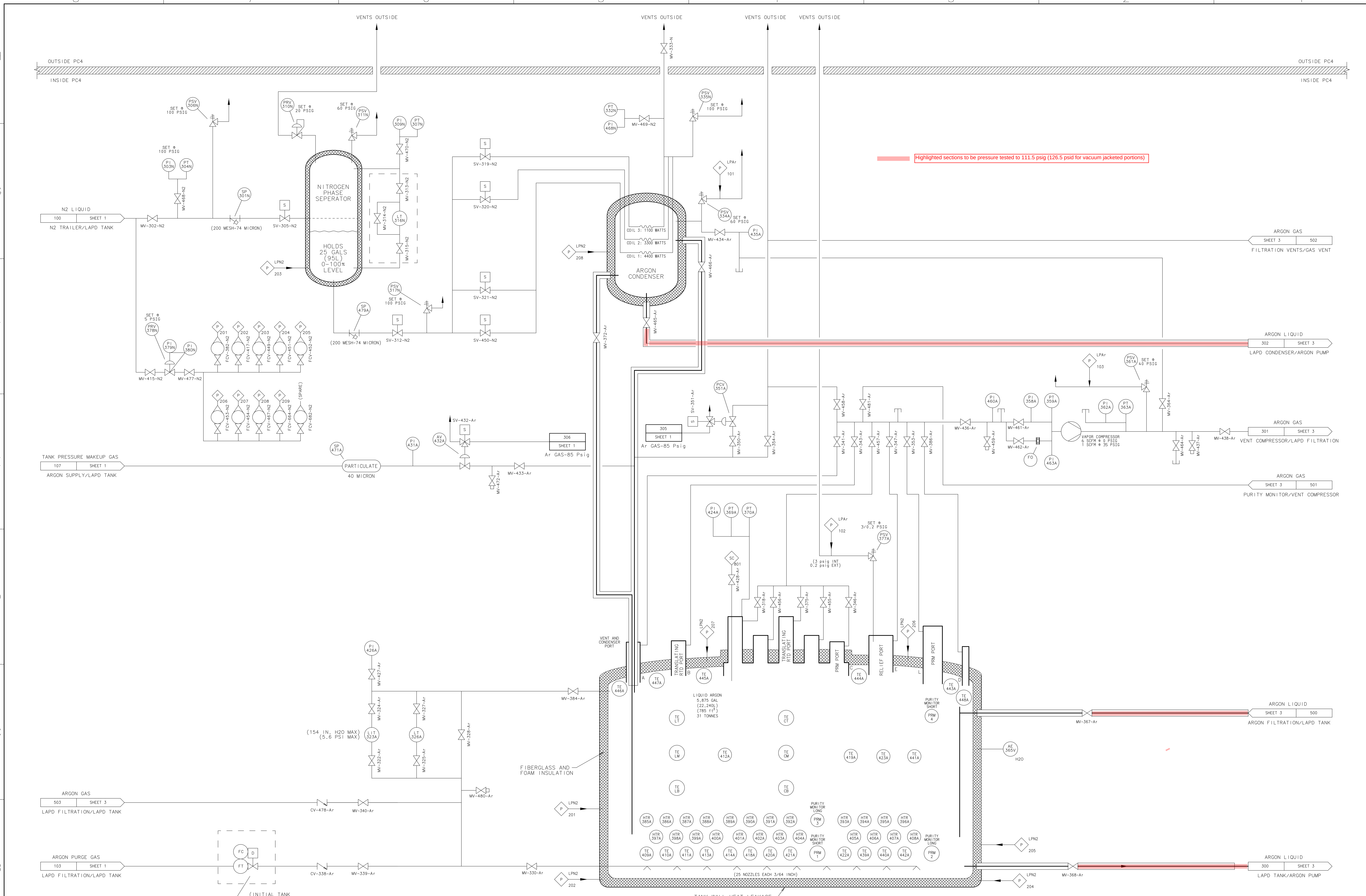
UNITED STATES DEPARTMENT OF ENERGY

FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	1 OF 4	K

CREATED WITH : Ideas12NXSeries | GROUP: PPD/MECHANICAL DEPARTMENT

Created: 13:21:58 on 20-06-11 (D-M-Y) By: catalan State: 1-INITIAL



UNLESS OTHERWISE SPECIFIED	ORIGINATOR	R.SCHMITT	26-JUN-2007
	DRAWN	J.CATALANELLO	07-DEC-2007
± ± ±	CHECKED	R.SCHMITT	12-DEC-2007
	APPROVED	R.SCHMITT	12-DEC-2007
1. BREAK ALL SHARP EDGES MAX. 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ASME Y14.5M-1994 4. MAX. ALL MACH. SURFACES 5. DRAWING UNITS: U.S. INCH	USED ON		
	MATERIAL		

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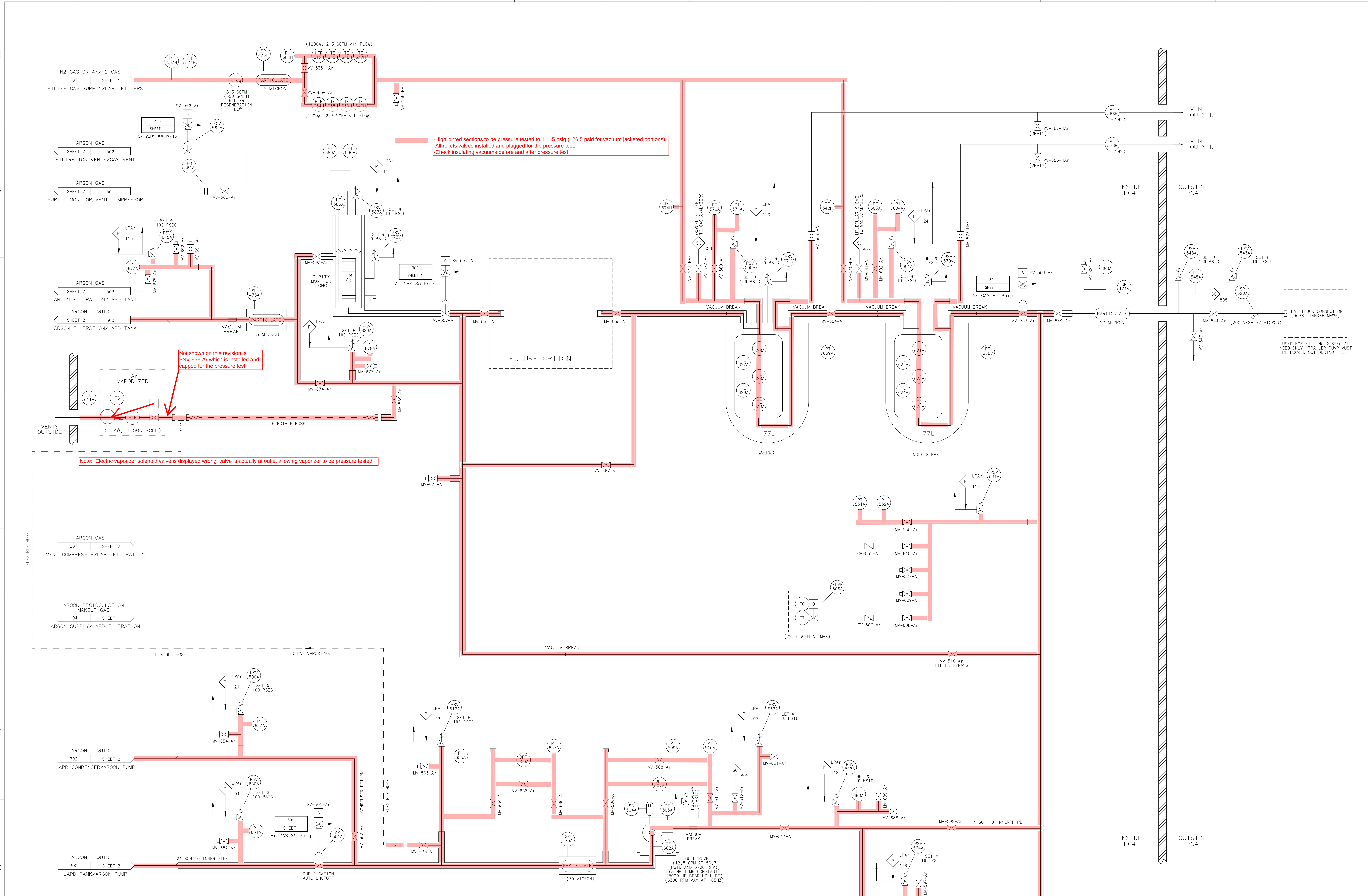
FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	2 OF 4	K

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

Created: 13:22:05 on 20-06-11 (D-M-Y) By: catalan State: 1-INITIAL



UNLESS OTHERWISE SPECIFIED	ORIGINATOR	R.SCHMITT	26-JUN-2007
	DRAWN	J.CATALANELLO	07-DEC-2007
	CHECKED	R.SCHMITT	12-DEC-2007
	APPROVED	R.SCHMITT	12-DEC-2007
1. BREAK ALL SHARP EDGES. 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ASME Y14.5M-1994 4. MAX. ALL MACH. SURFACES 5. DRAWING UNITS: U.S. INCH	USED ON		
	MATERIAL		

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FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	3 OF 4	K

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

Created: 13:22:13 on 20-06-11 (D-M-Y) By: catalan State: 1-INITIAL

Fermilab

Date: 10/3/12

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure 66 psig **Maximum Allowable Working Pressure** 60 psig
1.1 x 60 psig = 66 psig

Items to be Tested
LAPD liquid nitrogen supply piping at phase separator – see attached annotated flow schematic for highlighted test section.
Because FCV-305-N2 and FCV-312-N2 leak thru, the piping associated with it will also be at the test pressure.

Location of Test PC4 **Date and Time** 10/5/12 10:00Am

Hazards Involved
Stored energy of compressed gas.

Safety Precautions Taken
Test personnel will wear eye protection.
Supply pressure test manifold has a relief valve set just above 66 psig.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope
Dept/Date PPD/MD/

Division/Section Safety Officer RoB Bushelc
Dept/Date PPD/ES&H

Results
Phase separator held 66 psig. At 60 psig no leaks were detected over a 10 minute period. Terry Tope 13329N

Witness 15007N ES&H **Dept/Date** 10-5-12
(Safety Officer or Designee)

* Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

345.5 Pneumatic Leak Test

345.5.1 Precautions. Pneumatic testing involves the hazard of released energy stored in compressed gas. Particular care must therefore be taken to minimize the chance of brittle failure during a pneumatic leak test. Test temperature is important in this regard and must be considered when the designer chooses the material of construction. See para. 345.2.2(c) and Appendix F, para. F323.4.

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

345.5.3 Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

(10) **345.5.4 Test Pressure.** The test pressure shall be not less than 1.1 times the design pressure and shall not exceed the lesser of

(a) 1.33 times the design pressure

(b) the pressure that would produce a nominal pressure stress or longitudinal stress in excess of 90% of the yield strength of any component at the test temperature

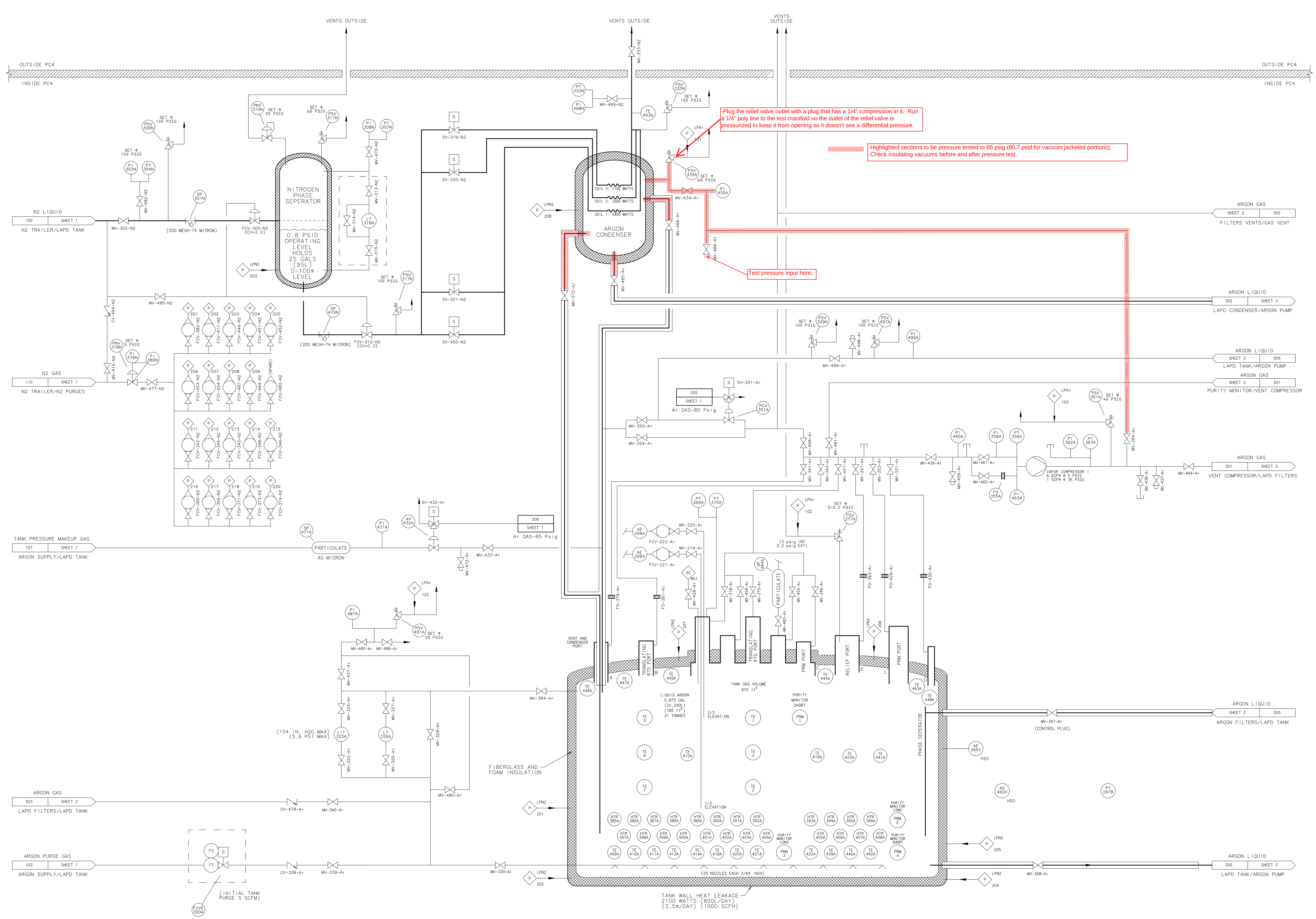
345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.2.2 Other Test Requirements

(a) Examination for Leaks. A leak test shall be maintained for at least 10 min, and all joints and connections shall be examined for leaks.

(b) Heat Treatment. Leak tests shall be conducted after any heat treatment has been completed.

(c) Low Test Temperature. The possibility of brittle fracture shall be considered when conducting leak tests at metal temperatures near the ductile-brittle transition temperature.



REV	DESCRIPTION	DRAWN / APPROVED	DATE

UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS:

ORIGINATOR	T.TOPE	26-JUN-2012
DRAWN	J.CATALANELLO	27-JUN-2012
CHECKED		
APPROVED		
USED ON		
MATERIAL		

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UNITED STATES DEPARTMENT OF ENERGY

MECHANICAL/ENG. DESIGN LAYOUTS
LBNE 35 TON PROTOTYPE
AND LAPD GAS PIPING LAYOUT

SCALE	DRAWING NUMBER	SHEET	REV
NONE	9219.000-ME-489811	2 OF 5	

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

Created: 09:39:55 on 14-09-12 (D-M-Y) By: catalan State: 1-INITIAL

Fermilab

Date: 11/1/12

EXHIBIT B
Pressure Testing Permit*

Type of Test: [ ]Hydrostatic [X] Pneumatic

Test Pressure	111.5 (126.5 psid to vacuum jacket	psig	**Maximum Allowable Working Pressure**	100 (115 psid, all components rated >=150 psid)	psig

Items to be Tested
LAPD purification piping – see attached sketch for details.

Location of Test PC4 **Date and Time** TBD 11/2/12 2pm

Hazards Involved
Stored energy of compressed gas

Safety Precautions Taken
Wear safety glasses.

Special Conditions or Requirements

Qualified Person and Test Coordinator Terry Tope [signature] 13324N 11/2/12
Dept/Date PPD/MD/

Division/Section Safety Officer Ross Buoshek
Dept/Date ESH / 11-2-12

Results
Piping held test pressure with no visible leaks. Vacuum jackets were checked before and after test. No sign of leakage into vacuum jackets as measured at DV6 gauges.

Witness [signature] /5007N **Dept/Date** ESH / 11/2/12
(Safety Officer or Designee)

- Must be signed by division/section safety officer prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

345.5 Pneumatic Leak Test

345.5.1 Precautions. Pneumatic testing involves the hazard of released energy stored in compressed gas. Particular care must therefore be taken to minimize the chance of brittle failure during a pneumatic leak test. Test temperature is important in this regard and must be considered when the designer chooses the material of construction. See para. 345.2.2(c) and Appendix F, para. F323.4.

345.5.2 Pressure Relief Device. A pressure relief device shall be provided, having a set pressure not higher than the test pressure plus the lesser of 345 kPa (50 psi) or 10% of the test pressure.

345.5.3 Test Fluid. The gas used as test fluid, if not air, shall be nonflammable and nontoxic.

(10) **345.5.4 Test Pressure.** The test pressure shall be not less than 1.1 times the design pressure and shall not exceed the lesser of

(a) 1.33 times the design pressure

(b) the pressure that would produce a nominal pressure stress or longitudinal stress in excess of 90% of the yield strength of any component at the test temperature

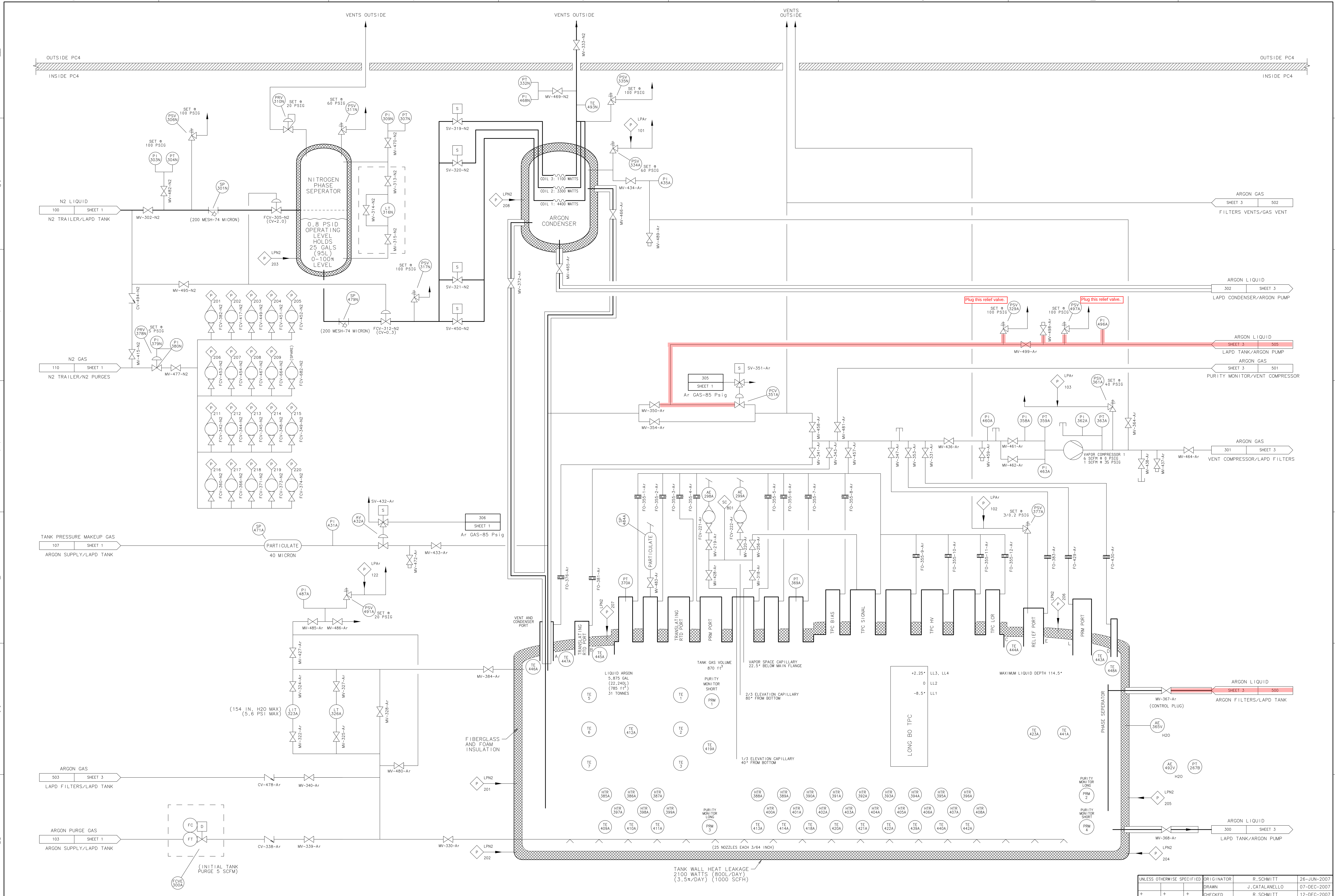
345.5.5 Procedure. The pressure shall be gradually increased until a gage pressure which is the lesser of one-half the test pressure or 170 kPa (25 psi) is attained, at which time a preliminary check shall be made, including examination of joints in accordance with para. 341.4.1(a). Thereafter, the pressure shall be gradually increased in steps until the test pressure is reached, holding the pressure at each step long enough to equalize piping strains. The pressure shall then be reduced to the design pressure before examining for leakage in accordance with para. 345.2.2(a).

345.2.2 Other Test Requirements

(a) Examination for Leaks. A leak test shall be maintained for at least 10 min, and all joints and connections shall be examined for leaks.

(b) Heat Treatment. Leak tests shall be conducted after any heat treatment has been completed.

(c) Low Test Temperature. The possibility of brittle fracture shall be considered when conducting leak tests at metal temperatures near the ductile-brittle transition temperature.



Purification Piping Pressure Test Schematic for LAPD Run 2

-Highlighted sections to be pressure tested to 111.5 psig (126.5 psid for vacuum jacketed portions).
-All reliefs valves installed and plugged for the pressure test.
-Check insulating vacuums before and after pressure test.

ORIGINATOR	R.SCHMITT	26-JUN-2007
DRAWN	J.CATALANELLO	07-DEC-2007
CHECKED	R.SCHMITT	12-DEC-2007
APPROVED	R.SCHMITT	12-DEC-2007

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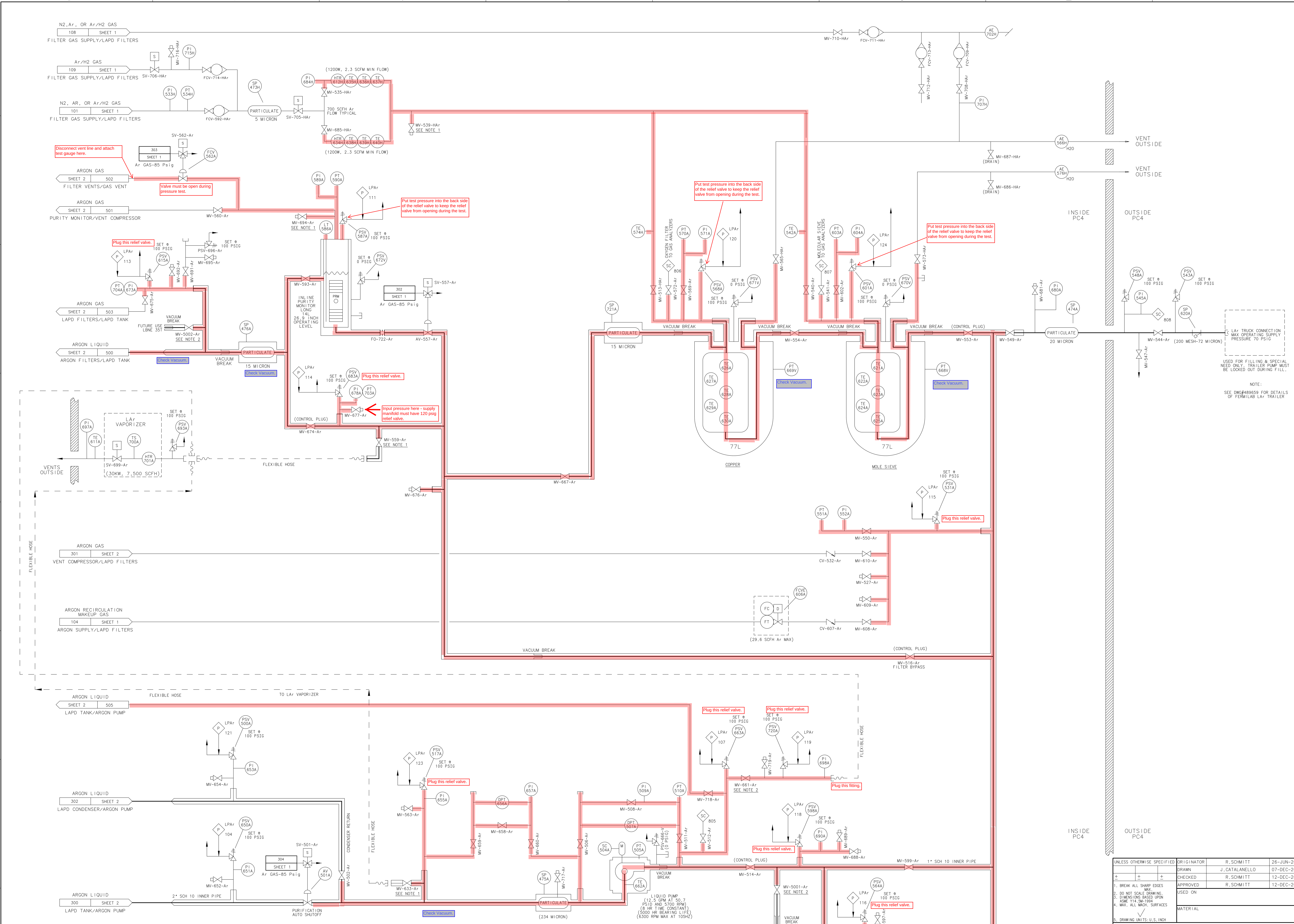
FLARE UTILITIES
GAS PIPING & INSTRUMENT DIAGRAM
LIQUID ARGON PURITY DEMONSTRAT'N

SCALE NONE — DRAWING NUMBER 3942.510-ME-444897 — SHEET 2 OF 4 — REV M

CREATED WITH: Ideas12NXSeries — GROUP: PPD/MECHANICAL DEPARTMENT

Created: 08:12:10 on 18-10-12 (D-M-Y) By: catalan State: 1-INITIAL



NOTES

1. VALVE TO REMAIN LOCKED CLOSED DURING NORMAL LAPD CRYOGENIC OPERATIONS. VALVE MAY ONLY BE UNLOCKED AND OPENED BY A PPD/MD/F&T ENGINEER FOLLOWING A RELEVANT PROCEDURE.
2. VALVE TO REMAIN LOCKED CLOSED DURING LAPD CRYOGENIC OPERATIONS.

-Highlighted sections to be pressure tested to 111.5 psig (126.5 psid for vacuum jacketed portions).
-All reliefs valves installed and plugged for the pressure test.
-Check insulating vacuums before and after pressure test.

UNLESS OTHERWISE SPECIFIED	ORIGINATOR	R.SCHMITT	26-JUN-2007
± ± ±	DRAWN	J.CATALANELLO	07-DEC-2007
	CHECKED	R.SCHMITT	12-DEC-2007
	APPROVED	R.SCHMITT	12-DEC-2007

1. BREAK ALL SHARP EDGES MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL

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FLARE UTILITIES GAS PIPING & INSTRUMENT DIAGRAM LIQUID ARGON PURITY DEMONSTRAT'N

SCALE	DRAWING NUMBER	SHEET	REV
NONE	3942.510-ME-444897	3 OF 4	M

CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

Created: 08:12:17 on 18-10-12 (D-M-Y) By: catalan State: 1-INITIAL

Appendix F
Engineering Equation Solver (EES) programs for relief valve calculations

```
{Trapped volume relief valve calculations for LAPD vacuum jacketed piping}

mli_thickness = 0.3937/12  {ft}  {assume 20 layers take up 1 centimeter of radial space, 1 cm = 0.3937 inches=0.0328 ft}

L_gap_mli = mli_thickness/20   {feet, gap between each of the mli layers}

k_air = Conductivity(Air_ha,T=T_f,P=14.7)  {thermal conductivity of air Btu / (hr, T_f is the average temperature between the two
 convection surfaces  }

Psat =1.1*100 +1.1*14.7  {flow rating pressure which is 110% of mawp calculated as per CGA S1.3 5.1.13}

T_ambient = 590.67   {R, ambient temperature of the air Btu / (hr x ft x R), 590 R =130 F = 55 C  }

{---------------------------------------------------------------------------------------------------------------}
{T1, T_o = the vacuum jacket inner surface}
{T2, T_i = the outer layer of mli}
{T21 = the inner layer of mli}
{T22 = cold pipe outer surface}
{r_mli, D_mli, D_i outer radius and outer diameter of the mli}
{r_1, D_1, D_ovinner radius and inner diameter of the vacuum jacket}

A_mli = PI*D_mli*L_pipe  {surface area of the outer layer of mli wrapping the pipe, ft^2}

qrad_12 = ABS(     A_mli*sigma*(T_2^4 - T_1^4)/(1/epsilon_mli + (1-epsilon_1)/epsilon_1*(D_mli/D_1) )    )  {radiation exchange
 between the vacuum jacket and the outer layer of super insulation Incropera and Dewitt 13.25}

{--------------------------------------------------}
{convection in concentric cylinders Incropera and Dewitt 9.58}

k_effective/k_air = 0.386*(Pr_air/(0.861 + Pr_air))^(0.25)*(Ra_cstar)^0.25   { Incropera and Dewitt 9.59}   {Ra_cstar range is 10^2
 to 10^7}

k_effective/k_air =convection_ratio   {ratio of the effective thermal conductivity to the stationary thermal conductivity}

Pr_air =Prandtl(Argon,T=T_f,P=14.7)

Ra_cstar = (LN (D_o/D_i))^4 / (  (L_gap^3)*(D_i^(-3/5) + D_o^(-3/5)^5))*Ra_L          { Incropera and Dewitt 9.60}

Ra_L = gravity*Beta*(T_o - T_i)*L_gap^3/(alpha_air*nu_air)

gravity = 32.2*3600^2  {ft/hr^2, 32.2 ft/s^2 x 3600^2 s^2/hr^2}
Beta = 1/T_f

{properties of air for free convection between the MLI OD and the vacuum jacket ID}
alpha_air = k_air/(rho_air*C_p_air)
rho_air =Density(Air_ha,T=T_f,P=14.7)
C_p_air=Cp(Air_ha,T=T_f,P=14.7)
Pr_air = nu_air/alpha_air

T_f = (T_i + T_o)/2   {R, film temperature at which properties are evaluated}

L_gap = (D_1 - D_mli)/2    {ft, the length for Ra_L is the width of the gap between the two pipes}
L_gap_inches = L_gap*12   {in, the length for Ra_L is the width of the gap between the two pipes}

D_o = D_1   {ft, inner diameter of the vacuum jacket}
D_i=D_mli    {ft, outer diameter of the mli covering the inner cryogen pipe}
T_i = T_2   {R, temperature of the OD of the MLI}
T_o = T_1  {R, vacuum jacket ID temperature}

{--------------------------------------------------}
{Radiation and convection in the open air space between the pipes}
```

```
qconv_12 = 2*PI*k_effective*(T_1-T_2)/(  ln(D_o/D_i)  )*L_pipe   {convection in the air space is modeled using an effective thermal
 conductivity that is > than the air thermal conductivity}

qrad_12 + qconv_12 = q_total        {the total heat flow is the sum of the radiation and conduction mechanisms, total heat flow
 between each component must be equal}
{---------------------------------------------------------------------------------------------------------------}
{radiation thru the mli shields are modeled as 1 D since the areas are ~equal}
qrad_23 = A_mli*sigma*(T_2^4 - T_3^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_23 = k_air*A_mli*(T_2-T_3)/L_gap_mli

qrad_23+ qcond_23 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_34 = A_mli*sigma*(T_3^4 - T_4^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_34 = k_air*A_mli*(T_3-T_4)/L_gap_mli

qrad_34+ qcond_34 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_45 = A_mli*sigma*(T_4^4 - T_5^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_45 = k_air*A_mli*(T_4-T_5)/L_gap_mli

qrad_45+ qcond_45 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_56 = A_mli*sigma*(T_5^4 - T_6^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_56 = k_air*A_mli*(T_5-T_6)/L_gap_mli

qrad_56+ qcond_56 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_67 = A_mli*sigma*(T_6^4 - T_7^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_67 = k_air*A_mli*(T_6-T_7)/L_gap_mli

qrad_67+ qcond_67 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_78 = A_mli*sigma*(T_7^4 - T_8^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_78 = k_air*A_mli*(T_7-T_8)/L_gap_mli

qrad_78+ qcond_78 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_89= A_mli*sigma*(T_8^4 - T_9^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_89 = k_air*A_mli*(T_8-T_9)/L_gap_mli

qrad_89+ qcond_89 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_910= A_mli*sigma*(T_9^4 - T_10^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_910 = k_air*A_mli*(T_9-T_10)/L_gap_mli

qrad_910+ qcond_910 = q_total
{---------------------------------------------------------------------------------------------------------------}
qrad_1011= A_mli*sigma*(T_10^4 - T_11^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1011 = k_air*A_mli*(T_10-T_11)/L_gap_mli
```

```
qrad_1011+ qcond_1011 = q_total
{-----------------------------------------------------------------------------------------------------------}

qrad_1112= A_mli*sigma*(T_11^4 - T_12^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1112 = k_air*A_mli*(T_11-T_12)/L_gap_mli

qrad_1112+ qcond_1112 = q_total
{-----------------------------------------------------------------------------------------------------------}

qrad_1213= A_mli*sigma*(T_12^4 - T_13^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1213 = k_air*A_mli*(T_12-T_13)/L_gap_mli

qrad_1213+ qcond_1213 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1314= A_mli*sigma*(T_13^4 - T_14^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1314 = k_air*A_mli*(T_13-T_14)/L_gap_mli

qrad_1314+ qcond_1314 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1415= A_mli*sigma*(T_14^4 - T_15^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1415 = k_air*A_mli*(T_14-T_15)/L_gap_mli

qrad_1415+ qcond_1415 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1516= A_mli*sigma*(T_15^4 - T_16^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1516= k_air*A_mli*(T_15-T_16)/L_gap_mli

qrad_1516+ qcond_1516 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1617= A_mli*sigma*(T_16^4 - T_17^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1617= k_air*A_mli*(T_16-T_17)/L_gap_mli

qrad_1617+ qcond_1617 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1718= A_mli*sigma*(T_17^4 - T_18^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1718= k_air*A_mli*(T_17-T_18)/L_gap_mli

qrad_1718+ qcond_1718 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1819= A_mli*sigma*(T_18^4 - T_19^4)/(1/epsilon_mli + 1/epsilon_mli - 1)
```

```
qcond_1819= k_air*A_mli*(T_18-T_19)/L_gap_mli

qrad_1819+ qcond_1819 = q_total

{--------------------------------------------------------------------------------------------------------------}

qrad_1920= A_mli*sigma*(T_19^4 - T_20^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1920= k_air*A_mli*(T_19-T_20)/L_gap_mli

qrad_1920+ qcond_1920 = q_total

{--------------------------------------------------------------------------------------------------------------}

qrad_2021= A_mli*sigma*(T_20^4 - T_21^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_2021= k_air*A_mli*(T_20-T_21)/L_gap_mli

qrad_2021+ qcond_2021 = q_total

{--------------------------------------------------------------------------------------------------------------}

qrad_2122= A_mli*sigma*(T_21^4 - T_22^4)/(1/epsilon_mli + 1/epsilon_22 - 1)

qcond_2122= k_air*A_mli*(T_21-T_22)/L_gap_mli

qrad_2122+ qcond_2122 = q_total

{--------------------------------------------------------------------------------------------------------------}

q_total_W = q_total*0.293  {convert Btu/hr to Watt}

sigma = 0.1714e-8  {Stefan-Boltzmann constant Btu / (hr *ft^2 * R^4)   }

epsilon_1 = 1   {surface emissivity of the ID of the vacuum jacket}

epsilon_mli = 0.05 {shield surface emissivity}

epsilon_22 = 1 {surface emissivity of the OD of the inner cryogen containing line}

L_pipe = 100    {!!!!! length of the piping section  in feet !!!!!}

T_1 =T_ambient    {vacuum jacket temperature in R}

T_22=Temperature(Argon,P=Psat,x=0)    {cryogen containing piping temperature in R at the flow rating saturation pressure}

D_1 = D_1_inches/12   {ft, inside diameter of the vacuum jacket}

D_1_inches = 3.26   {!!!! inches, inside diameter of the vacuum jacket !!!!!!}

D_22 = D_22_inches/12  {ft, outside diameter of the cryogenic pipe}

D_22_inches = 1.315   {!!!!!! inches, outside diameter of the cryogenic pipe!!!!!!! }

D_mli = D_22 + mli_thickness*2   {ft, outside diameter of the mli wrapping the cold pipe}

D_mli_inches = D_mli *12   {outside diameter of the mli in inches}

P_crticalcargon=P_crit(Argon)
```

{--}

{Piping trapped volume relief valve calulations using CGA S-1.3 for vacuum insulated piping}

{CGA calculations}

G_i=73.4*(1660-T)/(C*L)*SQRT(Z*T/M) *{gas factor for insulated containers for flow rating pressures below 40% of the critical presure from CGA notes for Tables 1 and Table 2}*

T=TEMPERATURE(Argon,x=0,P=Psat) *{Temperature as specified in 6.1.3 which is the saturation temperature at the flow rating pressure}*

C=377 *{constant for gas/vapor related to the ratio of specific heats}*

L=(ENTHALPY(Argon,x=1,P=P)-ENTHALPY(Argon,x=0,P=P)) *{latent heat at flow rating pressure in btu/lb}*

M=39.948 *{molecular weight of argon}*

Z = P*V*144/(R*T) *{compressibility factor}*

V=VOLUME(Argon,x=1,P=P) *{specific volume at flow rating pressure ft^3/lbm}*

R=1545/39.948 *{ideal gas constant}*

P =Psat *{flow rating pressure which is 110% of mawp calculated as per 5.1.13}*

{CGA S-1.3 2008 equation 6.2.2, required flow capacity for insulated containers for conditions other than fire}
Q_a = (590 - T)*F*G_i*U*A / (4*(1660-T)) *{SCFM air}*

F = 1 *{corrections factor specified in 6.1.4, =1 for relief valves mounted within 2 ft of the piping}*

A = A_mli *{ft^2, area used for CGA calcs}*

U = q_total/ (A*(T_1-T_22)) *{Btu / (hr * ft^2 * F}* *{over all heat transfer coefficient of the insulating material of the container when saturated with air}*

q_argon_check = q_total / (L*60*rho_Ar_stp) *{the calculated heat input into the argon creates a SCFM argon flow as a check}*

rho_Ar_stp=Density(Argon,T=519.67,P=14.7) *{argon density at standard conditions}*

$$mli_{thickness} = \frac{0.3937}{12}$$

$$L_{gap,mli} = \frac{mli_{thickness}}{20}$$

$$k_{air} = \mathbf{k}\left[\text{'Air}_{ha}\text{'}, T = T_f, P = 14.7 \right]$$

$$Psat = 1.1 \cdot 100 + 1.1 \cdot 14.7$$

$$T_{ambient} = 590.67$$

$$A_{mli} = \pi \cdot D_{mli} \cdot L_{pipe}$$

$$qrad_{12} = \left| A_{mli} \cdot \sigma \cdot \left[\frac{T_2^{\,4} - T_1^{\,4}}{\frac{1}{\varepsilon_{mli}} + \left(\frac{1 - \varepsilon_1}{\varepsilon_1} \right) \cdot \frac{D_{mli}}{D_1}} \right] \right|$$

$$\frac{k_{effective}}{k_{air}} = 0.386 \cdot \left[\frac{Pr_{air}}{0.861 + Pr_{air}} \right]^{0.25} \cdot Ra_{cstar}^{\ 0.25}$$

$$\frac{k_{effective}}{k_{air}} = convection_{ratio}$$

$$Pr_{air} = \mathbf{Pr} \left[\text{'Argon'} , T = T_f , P = 14.7 \right]$$

$$Ra_{cstar} = \frac{\mathbf{ln}^4 \left[\frac{D_o}{D_i} \right]}{L_{gap}^{\ 3} \cdot \left[D_i^{\left(\frac{-3}{5} \right)} + \left(D_o^{\left[\frac{-3}{5} \right]} \right)^5 \right]} \cdot Ra_L$$

$$Ra_L = gravity \cdot \beta \cdot \left[T_o - T_i \right] \cdot \frac{L_{gap}^{\ 3}}{\alpha_{air} \cdot \nu_{air}}$$

$$gravity = 32.2 \cdot 3600^2$$

$$\beta = \frac{1}{T_f}$$

$$\alpha_{air} = \frac{k_{air}}{\rho_{air} \cdot C_{p,air}}$$

$$\rho_{air} = \rho \left[\text{'Air}_{ha}\text{'} , T = T_f , P = 14.7 \right]$$

$$C_{p,air} = \mathbf{Cp} \left[\text{'Air}_{ha}\text{'} , T = T_f , P = 14.7 \right]$$

$$Pr_{air} = \frac{\nu_{air}}{\alpha_{air}}$$

$$T_f = \frac{T_i + T_o}{2}$$

$$L_{gap} = \frac{D_1 - D_{mli}}{2}$$

$$L_{gap,inches} = L_{gap} \cdot 12$$

$$D_o = D_1$$

$$D_i = D_{mli}$$

$$T_i = T_2$$

$$T_o = T_1$$

$$qconv_{12} = 2 \cdot \pi \cdot k_{effective} \cdot \left[\frac{T_1 - T_2}{\mathbf{ln} \left(\frac{D_o}{D_i} \right)} \right] \cdot L_{pipe}$$

$$qrad_{12} + qconv_{12} = q_{total}$$

$$qrad_{23} = A_{mli} \cdot \sigma \cdot \left[\frac{T_2^{\ 4} - T_3^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{23} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_2 - T_3}{L_{gap,mli}} \right]$$

$$qrad_{23} + qcond_{23} = q_{total}$$

$$qrad_{34} = A_{mli} \cdot \sigma \cdot \left[\frac{T_3^4 - T_4^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{34} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_3 - T_4}{L_{gap,mli}} \right]$$

$$qrad_{34} + qcond_{34} = q_{total}$$

$$qrad_{45} = A_{mli} \cdot \sigma \cdot \left[\frac{T_4^4 - T_5^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{45} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_4 - T_5}{L_{gap,mli}} \right]$$

$$qrad_{45} + qcond_{45} = q_{total}$$

$$qrad_{56} = A_{mli} \cdot \sigma \cdot \left[\frac{T_5^4 - T_6^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{56} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_5 - T_6}{L_{gap,mli}} \right]$$

$$qrad_{56} + qcond_{56} = q_{total}$$

$$qrad_{67} = A_{mli} \cdot \sigma \cdot \left[\frac{T_6^4 - T_7^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{67} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_6 - T_7}{L_{gap,mli}} \right]$$

$$qrad_{67} + qcond_{67} = q_{total}$$

$$qrad_{78} = A_{mli} \cdot \sigma \cdot \left[\frac{T_7^4 - T_8^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{78} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_7 - T_8}{L_{gap,mli}} \right]$$

$$qrad_{78} + qcond_{78} = q_{total}$$

$$qrad_{89} = A_{mli} \cdot \sigma \cdot \left[\frac{T_8^4 - T_9^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{89} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_8 - T_9}{L_{gap,mli}} \right]$$

$$qrad_{89} + qcond_{89} = q_{total}$$

$$qrad_{910} = A_{mli} \cdot \sigma \cdot \left[\frac{T_9^{\ 4} - T_{10}^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{910} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_9 - T_{10}}{L_{gap,mli}} \right]$$

$$qrad_{910} + qcond_{910} = q_{total}$$

$$qrad_{1011} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{10}^{\ 4} - T_{11}^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1011} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{10} - T_{11}}{L_{gap,mli}} \right]$$

$$qrad_{1011} + qcond_{1011} = q_{total}$$

$$qrad_{1112} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{11}^{\ 4} - T_{12}^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1112} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{11} - T_{12}}{L_{gap,mli}} \right]$$

$$qrad_{1112} + qcond_{1112} = q_{total}$$

$$qrad_{1213} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{12}^{\ 4} - T_{13}^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1213} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{12} - T_{13}}{L_{gap,mli}} \right]$$

$$qrad_{1213} + qcond_{1213} = q_{total}$$

$$qrad_{1314} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{13}^{\ 4} - T_{14}^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1314} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{13} - T_{14}}{L_{gap,mli}} \right]$$

$$qrad_{1314} + qcond_{1314} = q_{total}$$

$$qrad_{1415} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{14}^{\ 4} - T_{15}^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1415} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{14} - T_{15}}{L_{gap,mli}} \right]$$

$$qrad_{1415} + qcond_{1415} = q_{total}$$

$$qrad_{1516} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{15}^{4} - T_{16}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1516} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{15} - T_{16}}{L_{gap,mli}} \right]$$

$$qrad_{1516} + qcond_{1516} = q_{total}$$

$$qrad_{1617} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{16}^{4} - T_{17}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1617} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{16} - T_{17}}{L_{gap,mli}} \right]$$

$$qrad_{1617} + qcond_{1617} = q_{total}$$

$$qrad_{1718} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{17}^{4} - T_{18}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1718} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{17} - T_{18}}{L_{gap,mli}} \right]$$

$$qrad_{1718} + qcond_{1718} = q_{total}$$

$$qrad_{1819} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{18}^{4} - T_{19}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1819} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{18} - T_{19}}{L_{gap,mli}} \right]$$

$$qrad_{1819} + qcond_{1819} = q_{total}$$

$$qrad_{1920} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{19}^{4} - T_{20}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1920} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{19} - T_{20}}{L_{gap,mli}} \right]$$

$$qrad_{1920} + qcond_{1920} = q_{total}$$

$$qrad_{2021} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{20}^{4} - T_{21}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{2021} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{20} - T_{21}}{L_{gap,mli}} \right]$$

$$qrad_{2021} + qcond_{2021} = q_{total}$$

$$qrad_{2122} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{21}^{4} - T_{22}^{4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{22}} - 1} \right]$$

$$qcond_{2122} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{21} - T_{22}}{L_{gap,mli}} \right]$$

$$qrad_{2122} + qcond_{2122} = q_{total}$$

$$q_{total,W} = q_{total} \cdot 0.293$$

$$\sigma = 1.714 \times 10^{-9}$$

$$\varepsilon_1 = 1$$

$$\varepsilon_{mli} = 0.05$$

$$\varepsilon_{22} = 1$$

$$L_{pipe} = 100$$

$$T_1 = T_{ambient}$$

$$T_{22} = \mathbf{T}\left[\text{'Argon'} , P = Psat , x = 0 \right]$$

$$D_1 = \frac{D_{1,inches}}{12}$$

$$D_{1,inches} = 3.26$$

$$D_{22} = \frac{D_{22,inches}}{12}$$

$$D_{22,inches} = 1.315$$

$$D_{mli} = D_{22} + mli_{thickness} \cdot 2$$

$$D_{mli,inches} = D_{mli} \cdot 12$$

$$P_{crticalcargon} = \mathbf{P}_{Crit} \left[\text{'Argon'} \right]$$

$$G_i = 73.4 \cdot \left[\frac{1660 - T}{C \cdot L} \right] \cdot \sqrt{Z \cdot \frac{T}{M}}$$

$$T = \mathbf{T}\left[\text{'Argon'} , x = 0 , P = Psat \right]$$

$$C = 377$$

$$L = \mathbf{h}\left[\text{'Argon'} , x = 1 , P = P \right] - \mathbf{h}\left[\text{'Argon'} , x = 0 , P = P \right]$$

$$M = 39.948$$

$$Z = P \cdot V \cdot \frac{144}{R \cdot T}$$

$$V = \mathbf{v}\left[\text{'Argon'} , x = 1 , P = P \right]$$

$$R = \frac{1545}{39.948}$$

$$P = Psat$$

$$Q_a = [590 - T] \cdot F \cdot G_i \cdot U \cdot \frac{A}{4 \cdot [1660 - T]}$$

$$F = 1$$

$$A = A_{mli}$$

$$U = \frac{q_{total}}{A \cdot [T_1 - T_{22}]}$$

$$q_{argon,check} = \frac{q_{total}}{L \cdot 60 \cdot \rho_{Ar,stp}}$$

$$\rho_{Ar,stp} = \rho['Argon', T = 519.67, P = 14.7]$$

SOLUTION

Unit Settings: [R]/[psia]/[lbm]/[degrees]

A = 55.04 [ft^2]
A_{mli} = 55.04 [ft^2]
C = 377
$C_{p,air}$ = 0.2405 [Btu/lbm-R]
$D_{1,inches}$ = 3.26 [in]
$D_{22,inches}$ = 1.315 [in]
D_{mli} = 0.1752 [ft]
D_o = 0.2717 [ft]
ε_{22} = 1
F = 1
G_i = 9.715 [ ]
$k_{effective}$ = 0.07906 [Btu / (hr*ft*R)]
L_{gap} = 0.04823 [ft]
$L_{gap,mli}$ = 0.00164 [ft]
M = 39.95
ν_{air} = 0.6038 [ft^2/hr]
Pr_{air} = 0.6648 [ ]
$P_{crticalcargon}$ = 705.3 [psia]
$qcond_{1112}$ = 8231 [Btu/hr]
$qcond_{1314}$ = 8233 [Btu/hr]
$qcond_{1516}$ = 8234 [Btu/hr]
$qcond_{1718}$ = 8235 [Btu/hr]
$qcond_{1920}$ = 8236 [Btu/hr]
$qcond_{2122}$ = 8236 [Btu/hr]
$qcond_{34}$ = 8220 [Btu/hr]
$qcond_{56}$ = 8223 [Btu/hr]
$qcond_{78}$ = 8226 [Btu/hr]
$qcond_{910}$ = 8229 [Btu/hr]
$qrad_{1011}$ = 8.78 [Btu/hr]
$qrad_{12}$ = 229.424 [Btu/hr]
$qrad_{1314}$ = 5.946 [Btu/hr]
$qrad_{1516}$ = 4.442 [Btu/hr]
$qrad_{1718}$ = 3.216 [Btu/hr]
$qrad_{1920}$ = 2.24 [Btu/hr]
$qrad_{2122}$ = 2.892 [Btu/hr]
$qrad_{34}$ = 18.58 [Btu/hr]
$qrad_{56}$ = 15.28 [Btu/hr]
$qrad_{78}$ = 12.39 [Btu/hr]
$qrad_{910}$ = 9.894 [Btu/hr]
$q_{argon,check}$ = 21.48 [SCFM]
$q_{total,W}$ = 2414 [W]

α_{air} = 0.9082 [ft^2/hr]
β = 0.001801 [1/R]
$convection_{ratio}$ = 5.065
D_1 = 0.2717 [ft]
D_{22} = 0.1096 [in]
D_i = 0.1752 [ft]
$D_{mli,inches}$ = 2.102 [in]
ε_1 = 1
ε_{mli} = 0.05
gravity = 4.173E+08 [ft/hr^2]
k_{air} = 0.01561 [Btu / (hr*ft*R)]
L = 60.68 [Btu/lbm]
$L_{gap,inches}$ = 0.5788 [in]
L_{pipe} = 100.00 [ft]
$mli_{thickness}$ = 0.03281 [ft]
P = 126.2 [psia]
Psat = 126.2 [psia]
$qcond_{1011}$ = 8230 [Btu/hr]
$qcond_{1213}$ = 8232 [Btu/hr]
$qcond_{1415}$ = 8233 [Btu/hr]
$qcond_{1617}$ = 8235 [Btu/hr]
$qcond_{1819}$ = 8236 [Btu/hr]
$qcond_{2021}$ = 8237 [Btu/hr]
$qcond_{23}$ = 8218 [Btu/hr]
$qcond_{45}$ = 8222 [Btu/hr]
$qcond_{67}$ = 8225 [Btu/hr]
$qcond_{89}$ = 8228 [Btu/hr]
$qconv_{12}$ = 8009 [Btu/hr]
$qrad_{1112}$ = 7.753 [Btu/hr]
$qrad_{1213}$ = 6.81 [Btu/hr]
$qrad_{1415}$ = 5.158 [Btu/hr]
$qrad_{1617}$ = 3.797 [Btu/hr]
$qrad_{1819}$ = 2.699 [Btu/hr]
$qrad_{2021}$ = 1.836 [Btu/hr]
$qrad_{23}$ = 20.4 [Btu/hr]
$qrad_{45}$ = 16.88 [Btu/hr]
$qrad_{67}$ = 13.79 [Btu/hr]
$qrad_{89}$ = 11.1 [Btu/hr]
Q_a = 13.73 [SCFM]
q_{total} = 8238.605 [Btu/hr]
R = 38.68

Ra_{cstar} = 68057
Ra_L = 10875 [ ]
ρ_{air} = 0.07145 [lb_m/ft^3]
$\rho_{Ar,stp}$ = 0.1054 [lb_m/ft^3]
σ = 1.714E-09 [Btu / (hr*ft^2 * $R^{4)}$]
T = 205.7 [R]
T_1 = 590.7 [R]
T_{10} = 394.3 [R]
T_{11} = 378.6 [R]
T_{12} = 362.9 [R]
T_{13} = 347.2 [R]
T_{14} = 331.5 [R]
T_{15} = 315.7 [R]
T_{16} = 300 [R]
T_{17} = 284.3 [R]
T_{18} = 268.6 [R]
T_{19} = 252.8 [R]
T_2 = 519.949 [R]
T_{20} = 237.11 [R]
T_{21} = 221.4 [R]
T_{22} = 205.7 [R]
T_3 = 504.3 [R]
T_4 = 488.6 [R]
T_5 = 472.9 [R]
T_6 = 457.2 [R]
T_7 = 441.5 [R]
T_8 = 425.7 [R]
T_9 = 410 [R]
$T_{ambient}$ = 590.7 [R]
T_f = 555.3 [R]
T_i = 519.9 [R]
T_o = 590.670 [R]
U = 0.3888 [Btu/hr-ft^2-R]
V = 0.3685 [ft^3/lb_m]
Z = 0.8418 [ ]

54 potential unit problems were detected.
EES suggested units (shown in purple) for D_22 D_i T T_f T_i .

```
{Trapped volume relief valve calculations for LAPD vacuum jacketed piping}

mli_thickness = 0.3937/12  {ft}  {assume 20 layers take up 1 centimeter of radial space, 1 cm = 0.3937 inches=0.0328 ft}

L_gap_mli = mli_thickness/20   {feet, gap between each of the mli layers}

k_air = Conductivity(Air_ha,T=T_f,P=14.7)  {thermal conductivity of air Btu / hr, T_f is the average temperature between the two
 convection surfaces  }

Psat =1.1*100 +1.1*14.7  {flow rating pressure which is 110% of mawp calculated as per CGA S1.3 5.1.13}

T_ambient = 590.67   {R, ambient temperature of the air Btu / (hr x ft x R), 590 R =130 F = 55 C  }

{-----------------------------------------------------------------------------------------------------------------}
{T1, T_o = the vacuum jacket inner surface}
{T2, T_i = the outer layer of mli}
{T21 = the inner layer of mli}
{T22 = cold pipe outer surface}
{r_mli, D_mli, D_i outer radius and outer diameter of the mli}
{r_1, D_1, D_ovinner radius and inner diameter of the vacuum jacket}

A_mli = PI*D_mli*L_pipe  {surface area of the outer layer of mli wrapping the pipe, ft^2}

qrad_12 = ABS(     A_mli*sigma*(T_2^4 - T_1^4)/(1/epsilon_mli + (1-epsilon_1)/epsilon_1*(D_mli/D_1) )    )  {radiation exchange
 between the vacuum jacket and the outer layer of super insulation Incropera and Dewitt 13.25}

{---------------------------------------------------}
{convection in concentric cylinders Incropera and Dewitt 9.58}

k_effective/k_air = 0.386*(Pr_air/(0.861 + Pr_air))^(0.25)*(Ra_cstar)^0.25   { Incropera and Dewitt 9.59}  {Ra_cstar range is 10^2
 to 10^7}

k_effective/k_air =convection_ratio   {ratio of the effective thermal conductivity to the stationary thermal conductivity}

Pr_air =Prandtl(Argon,T=T_f,P=14.7)

Ra_cstar = (LN (D_o/D_i))^4 / (  (L_gap^3)*(D_i^(-3/5) + D_o^(-3/5)^5))*Ra_L          { Incropera and Dewitt 9.60}

Ra_L = gravity*Beta*(T_o - T_i)*L_gap^3/(alpha_air*nu_air)

gravity = 32.2*3600^2  {ft/hr^2, 32.2 ft/s^2 x 3600^2 s^2/hr^2}
Beta = 1/T_f

{properties of air for free convection between the MLI OD and the vacuum jacket ID}
alpha_air = k_air/(rho_air*C_p_air)
rho_air =Density(Air_ha,T=T_f,P=14.7)
C_p_air=Cp(Air_ha,T=T_f,P=14.7)
Pr_air = nu_air/alpha_air

T_f = (T_i + T_o)/2   {R, film temperature at which properties are evaluated}

L_gap = (D_1 - D_mli)/2    {ft, the length for Ra_L is the width of the gap between the two pipes}
L_gap_inches = L_gap*12   {in, the length for Ra_L is the width of the gap between the two pipes}

D_o = D_1   {ft, inner diameter of the vacuum jacket}
D_i=D_mli    {ft, outer diameter of the mli covering the inner cryogen pipe}
T_i = T_2   {R, temperature of the OD of the MLI}
T_o = T_1  {R, vacuum jacket ID temperature}

{---------------------------------------------------}
{Radiation and convection in the open air space between the pipes}
```

```
qconv_12 = 2*PI*k_effective*(T_1-T_2)/(  ln(D_o/D_i)  )*L_pipe   {convection in the air space is modeled using an effective thermal
 conductivity that is > than the air thermal conductivity}

qrad_12 + qconv_12 = q_total       {the total heat flow is the sum of the radiation and conduction mechanisms, total heat flow
 between each component must be equal}
{------------------------------------------------------------------------------------------------------------------------}
{radiation thru the mli shields are modeled as 1 D since the areas are ~equal}
qrad_23 = A_mli*sigma*(T_2^4 - T_3^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_23 = k_air*A_mli*(T_2-T_3)/L_gap_mli

qrad_23+ qcond_23 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_34 = A_mli*sigma*(T_3^4 - T_4^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_34 = k_air*A_mli*(T_3-T_4)/L_gap_mli

qrad_34+ qcond_34 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_45 = A_mli*sigma*(T_4^4 - T_5^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_45 = k_air*A_mli*(T_4-T_5)/L_gap_mli

qrad_45+ qcond_45 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_56 = A_mli*sigma*(T_5^4 - T_6^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_56 = k_air*A_mli*(T_5-T_6)/L_gap_mli

qrad_56+ qcond_56 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_67 = A_mli*sigma*(T_6^4 - T_7^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_67 = k_air*A_mli*(T_6-T_7)/L_gap_mli

qrad_67+ qcond_67 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_78 = A_mli*sigma*(T_7^4 - T_8^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_78 = k_air*A_mli*(T_7-T_8)/L_gap_mli

qrad_78+ qcond_78 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_89= A_mli*sigma*(T_8^4 - T_9^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_89 = k_air*A_mli*(T_8-T_9)/L_gap_mli

qrad_89+ qcond_89 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_910= A_mli*sigma*(T_9^4 - T_10^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_910 = k_air*A_mli*(T_9-T_10)/L_gap_mli

qrad_910+ qcond_910 = q_total
{------------------------------------------------------------------------------------------------------------------------}
qrad_1011= A_mli*sigma*(T_10^4 - T_11^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1011 = k_air*A_mli*(T_10-T_11)/L_gap_mli
```

```
qrad_1011+ qcond_1011 = q_total
{-----------------------------------------------------------------------------------------------------------}

qrad_1112= A_mli*sigma*(T_11^4 - T_12^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1112 = k_air*A_mli*(T_11-T_12)/L_gap_mli

qrad_1112+ qcond_1112 = q_total
{-----------------------------------------------------------------------------------------------------------}

qrad_1213= A_mli*sigma*(T_12^4 - T_13^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1213 = k_air*A_mli*(T_12-T_13)/L_gap_mli

qrad_1213+ qcond_1213 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1314= A_mli*sigma*(T_13^4 - T_14^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1314 = k_air*A_mli*(T_13-T_14)/L_gap_mli

qrad_1314+ qcond_1314 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1415= A_mli*sigma*(T_14^4 - T_15^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1415 = k_air*A_mli*(T_14-T_15)/L_gap_mli

qrad_1415+ qcond_1415 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1516= A_mli*sigma*(T_15^4 - T_16^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1516= k_air*A_mli*(T_15-T_16)/L_gap_mli

qrad_1516+ qcond_1516 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1617= A_mli*sigma*(T_16^4 - T_17^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1617= k_air*A_mli*(T_16-T_17)/L_gap_mli

qrad_1617+ qcond_1617 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1718= A_mli*sigma*(T_17^4 - T_18^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1718= k_air*A_mli*(T_17-T_18)/L_gap_mli

qrad_1718+ qcond_1718 = q_total

{-----------------------------------------------------------------------------------------------------------}

qrad_1819= A_mli*sigma*(T_18^4 - T_19^4)/(1/epsilon_mli + 1/epsilon_mli - 1)
```

```
qcond_1819= k_air*A_mli*(T_18-T_19)/L_gap_mli

qrad_1819+ qcond_1819 = q_total

{------------------------------------------------------------------------------------------------------------------}

qrad_1920= A_mli*sigma*(T_19^4 - T_20^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_1920= k_air*A_mli*(T_19-T_20)/L_gap_mli

qrad_1920+ qcond_1920 = q_total

{------------------------------------------------------------------------------------------------------------------}

qrad_2021= A_mli*sigma*(T_20^4 - T_21^4)/(1/epsilon_mli + 1/epsilon_mli - 1)

qcond_2021= k_air*A_mli*(T_20-T_21)/L_gap_mli

qrad_2021+ qcond_2021 = q_total

{------------------------------------------------------------------------------------------------------------------}

qrad_2122= A_mli*sigma*(T_21^4 - T_22^4)/(1/epsilon_mli + 1/epsilon_22 - 1)

qcond_2122= k_air*A_mli*(T_21-T_22)/L_gap_mli

qrad_2122+ qcond_2122 = q_total

{------------------------------------------------------------------------------------------------------------------}

q_total_W = q_total*0.293  {convert Btu/hr to Watt}

sigma = 0.1714e-8  {Stefan-Boltzmann constant Btu / (hr *ft^2 * R^4)   }

epsilon_1 = 1   {surface emissivity of the ID of the vacuum jacket}

epsilon_mli = 0.05 {shield surface emissivity}

epsilon_22 = 1 {surface emissivity of the OD of the inner cryogen containing line}

L_pipe = 100    {length of the piping section  in feet}

T_1 =T_ambient    {vacuum jacket temperature in R}

T_22=Temperature(Argon,P=Psat,x=0)    {cryogen containing piping temperature in R at the flow rating saturation pressure}

D_1 = D_1_inches/12   {ft, inside diameter of the vacuum jacket}

D_1_inches = 5.295   {inches, inside diameter of the vacuum jacket}

D_22 = D_22_inches/12  {ft, outside diameter of the cryogenic pipe}

D_22_inches = 2.375   {inches, outside diameter of the cryogenic pipe}

D_mli = D_22 + mli_thickness*2   {ft, outside diameter of the mli wrapping the cold pipe}

D_mli_inches = D_mli *12   {outside diameter of the mli in inches}

P_crticalcargon=P_crit(Argon)
```

{---}

{Piping trapped volume relief valve calulations using CGA S-1.3 for vacuum insulated piping}

{CGA calculations}

G_i=73.4*(1660-T)/(C*L)*SQRT(Z*T/M) *{gas factor for insulated containers for flow rating pressures below 40% of the critical presure from CGA notes for Tables 1 and Table 2}*

T=TEMPERATURE(Argon,x=0,P=Psat) *{Temperature as specified in 6.1.3 which is the saturation temperature at the flow rating pressure}*

C=377 *{constant for gas/vapor related to the ratio of specific heats}*

L=(ENTHALPY(Argon,x=1,P=P)-ENTHALPY(Argon,x=0,P=P)) *{latent heat at flow rating pressure in btu/lb}*

M=39.948 *{molecular weight of argon}*

Z = P*V*144/(R*T) *{compressibility factor}*

V=VOLUME(Argon,x=1,P=P) *{specific volume at flow rating pressure ft^3/lbm}*

R=1545/39.948 *{ideal gas constant}*

P =Psat *{flow rating pressure which is 110% of mawp calculated as per 5.1.13}*

{CGA S-1.3 2008 equation 6.2.2, required flow capacity for insulated containers for conditions other than fire}
Q_a = (590 - T)*F*G_i*U*A / (4*(1660-T)) *{SCFM air}*

F = 1 *{corrections factor specified in 6.1.4, =1 for relief valves mounted within 2 ft of the piping}*

A = A_mli *{ft^2, area used for CGA calcs}*

U = q_total/ (A*(T_1-T_22)) *{Btu / (hr * ft^2 * F}* *{over all heat transfer coefficient of the insulating material of the container when saturated with air}*

q_argon_check = q_total / (L*60*rho_Ar_stp) *{the calculated heat input into the argon creates a SCFM argon flow as a check}*

rho_Ar_stp=Density(Argon,T=519.67,P=14.7) *{argon density at standard conditions}*

$$mli_{thickness} = \frac{0.3937}{12}$$

$$L_{gap,mli} = \frac{mli_{thickness}}{20}$$

$$k_{air} = \mathbf{k}\left[\text{'Air}_{ha}\text{'}\ , T = T_f, P = 14.7\right]$$

$$Psat = 1.1 \cdot 100 + 1.1 \cdot 14.7$$

$$T_{ambient} = 590.67$$

$$A_{mli} = \pi \cdot D_{mli} \cdot L_{pipe}$$

$$qrad_{12} = \left| A_{mli} \cdot \sigma \cdot \left[\frac{T_2^{\ 4} - T_1^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \left(\frac{1 - \varepsilon_1}{\varepsilon_1} \right) \cdot \frac{D_{mli}}{D_1}} \right] \right|$$

$$\frac{k_{effective}}{k_{air}} = 0.386 \cdot \left[\frac{Pr_{air}}{0.861 + Pr_{air}}\right]^{0.25} \cdot Ra_{cstar}^{\ 0.25}$$

$$\frac{k_{effective}}{k_{air}} = convection_{ratio}$$

$$Pr_{air} = \mathbf{Pr}\left[\text{'Argon'}, T=T_f, P=14.7\right]$$

$$Ra_{cstar} = \frac{\mathbf{ln}^4\left[\frac{D_o}{D_i}\right]}{L_{gap}^{\ 3} \cdot \left[D_i^{\left(\frac{-3}{5}\right)} + \left(D_o^{\left[\frac{-3}{5}\right]}\right)\right]^5} \cdot Ra_L$$

$$Ra_L = gravity \cdot \beta \cdot \left[T_o - T_i\right] \cdot \frac{L_{gap}^{\ 3}}{\alpha_{air} \cdot \nu_{air}}$$

$$gravity = 32.2 \cdot 3600^2$$

$$\beta = \frac{1}{T_f}$$

$$\alpha_{air} = \frac{k_{air}}{\rho_{air} \cdot C_{p,air}}$$

$$\rho_{air} = \rho\left[\text{'Air}_{ha}\text{'}, T=T_f, P=14.7\right]$$

$$C_{p,air} = \mathbf{Cp}\left[\text{'Air}_{ha}\text{'}, T=T_f, P=14.7\right]$$

$$Pr_{air} = \frac{\nu_{air}}{\alpha_{air}}$$

$$T_f = \frac{T_i + T_o}{2}$$

$$L_{gap} = \frac{D_1 - D_{mli}}{2}$$

$$L_{gap,inches} = L_{gap} \cdot 12$$

$$D_o = D_1$$

$$D_i = D_{mli}$$

$$T_i = T_2$$

$$T_o = T_1$$

$$qconv_{12} = 2 \cdot \pi \cdot k_{effective} \cdot \left[\frac{T_1 - T_2}{\mathbf{ln}\left(\frac{D_o}{D_i}\right)}\right] \cdot L_{pipe}$$

$$qrad_{12} + qconv_{12} = q_{total}$$

$$qrad_{23} = A_{mli} \cdot \sigma \cdot \left[\frac{T_2^{\ 4} - T_3^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1}\right]$$

$$qcond_{23} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_2 - T_3}{L_{gap,mli}} \right]$$

$$qrad_{23} + qcond_{23} = q_{total}$$

$$qrad_{34} = A_{mli} \cdot \sigma \cdot \left[\frac{T_3^{\ 4} - T_4^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{34} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_3 - T_4}{L_{gap,mli}} \right]$$

$$qrad_{34} + qcond_{34} = q_{total}$$

$$qrad_{45} = A_{mli} \cdot \sigma \cdot \left[\frac{T_4^{\ 4} - T_5^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{45} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_4 - T_5}{L_{gap,mli}} \right]$$

$$qrad_{45} + qcond_{45} = q_{total}$$

$$qrad_{56} = A_{mli} \cdot \sigma \cdot \left[\frac{T_5^{\ 4} - T_6^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{56} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_5 - T_6}{L_{gap,mli}} \right]$$

$$qrad_{56} + qcond_{56} = q_{total}$$

$$qrad_{67} = A_{mli} \cdot \sigma \cdot \left[\frac{T_6^{\ 4} - T_7^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{67} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_6 - T_7}{L_{gap,mli}} \right]$$

$$qrad_{67} + qcond_{67} = q_{total}$$

$$qrad_{78} = A_{mli} \cdot \sigma \cdot \left[\frac{T_7^{\ 4} - T_8^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{78} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_7 - T_8}{L_{gap,mli}} \right]$$

$$qrad_{78} + qcond_{78} = q_{total}$$

$$qrad_{89} = A_{mli} \cdot \sigma \cdot \left[\frac{T_8^{\ 4} - T_9^{\ 4}}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{89} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_8 - T_9}{L_{gap,mli}} \right]$$

$$qrad_{89} + qcond_{89} = q_{total}$$

$$qrad_{910} = A_{mli} \cdot \sigma \cdot \left[\frac{T_9{}^4 - T_{10}{}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{910} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_9 - T_{10}}{L_{gap,mli}} \right]$$

$$qrad_{910} + qcond_{910} = q_{total}$$

$$qrad_{1011} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{10}{}^4 - T_{11}{}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1011} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{10} - T_{11}}{L_{gap,mli}} \right]$$

$$qrad_{1011} + qcond_{1011} = q_{total}$$

$$qrad_{1112} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{11}{}^4 - T_{12}{}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1112} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{11} - T_{12}}{L_{gap,mli}} \right]$$

$$qrad_{1112} + qcond_{1112} = q_{total}$$

$$qrad_{1213} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{12}{}^4 - T_{13}{}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1213} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{12} - T_{13}}{L_{gap,mli}} \right]$$

$$qrad_{1213} + qcond_{1213} = q_{total}$$

$$qrad_{1314} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{13}{}^4 - T_{14}{}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1314} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{13} - T_{14}}{L_{gap,mli}} \right]$$

$$qrad_{1314} + qcond_{1314} = q_{total}$$

$$qrad_{1415} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{14}{}^4 - T_{15}{}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1415} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{14} - T_{15}}{L_{gap,mli}} \right]$$

$$qrad_{1415} + qcond_{1415} = q_{total}$$

$$qrad_{1516} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{15}^4 - T_{16}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1516} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{15} - T_{16}}{L_{gap,mli}} \right]$$

$$qrad_{1516} + qcond_{1516} = q_{total}$$

$$qrad_{1617} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{16}^4 - T_{17}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1617} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{16} - T_{17}}{L_{gap,mli}} \right]$$

$$qrad_{1617} + qcond_{1617} = q_{total}$$

$$qrad_{1718} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{17}^4 - T_{18}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1718} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{17} - T_{18}}{L_{gap,mli}} \right]$$

$$qrad_{1718} + qcond_{1718} = q_{total}$$

$$qrad_{1819} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{18}^4 - T_{19}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1819} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{18} - T_{19}}{L_{gap,mli}} \right]$$

$$qrad_{1819} + qcond_{1819} = q_{total}$$

$$qrad_{1920} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{19}^4 - T_{20}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{1920} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{19} - T_{20}}{L_{gap,mli}} \right]$$

$$qrad_{1920} + qcond_{1920} = q_{total}$$

$$qrad_{2021} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{20}^4 - T_{21}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{mli}} - 1} \right]$$

$$qcond_{2021} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{20} - T_{21}}{L_{gap,mli}} \right]$$

$$qrad_{2021} + qcond_{2021} = q_{total}$$

$$qrad_{2122} = A_{mli} \cdot \sigma \cdot \left[\frac{T_{21}^4 - T_{22}^4}{\frac{1}{\varepsilon_{mli}} + \frac{1}{\varepsilon_{22}} - 1} \right]$$

$$qcond_{2122} = k_{air} \cdot A_{mli} \cdot \left[\frac{T_{21} - T_{22}}{L_{gap,mli}} \right]$$

$$qrad_{2122} + qcond_{2122} = q_{total}$$

$$q_{total,W} = q_{total} \cdot 0.293$$

$$\sigma = 1.714 \times 10^{-9}$$

$$\varepsilon_1 = 1$$

$$\varepsilon_{mli} = 0.05$$

$$\varepsilon_{22} = 1$$

$$L_{pipe} = 100$$

$$T_1 = T_{ambient}$$

$$T_{22} = \mathbf{T}\left[\text{'Argon'} , P = Psat , x = 0 \right]$$

$$D_1 = \frac{D_{1,inches}}{12}$$

$$D_{1,inches} = 5.295$$

$$D_{22} = \frac{D_{22,inches}}{12}$$

$$D_{22,inches} = 2.375$$

$$D_{mli} = D_{22} + mli_{thickness} \cdot 2$$

$$D_{mli,inches} = D_{mli} \cdot 12$$

$$P_{crticalcargon} = \mathbf{P}_{Crit} \left[\text{'Argon'} \right]$$

$$G_i = 73.4 \cdot \left[\frac{1660 - T}{C \cdot L} \right] \cdot \sqrt{Z \cdot \frac{T}{M}}$$

$$T = \mathbf{T}\left[\text{'Argon'} , x = 0 , P = Psat \right]$$

$$C = 377$$

$$L = \mathbf{h}\left[\text{'Argon'} , x = 1 , P = P \right] - \mathbf{h}\left[\text{'Argon'} , x = 0 , P = P \right]$$

$$M = 39.948$$

$$Z = P \cdot V \cdot \frac{144}{R \cdot T}$$

$$V = \mathbf{v}\left[\text{'Argon'} , x = 1 , P = P \right]$$

$$R = \frac{1545}{39.948}$$

$$P = Psat$$

$$Q_a = [590 - T] \cdot F \cdot G_i \cdot U \cdot \frac{A}{4 \cdot [1660 - T]}$$

$$F = 1$$

$$A = A_{mli}$$

$$U = \frac{q_{total}}{A \cdot [T_1 - T_{22}]}$$

$$q_{argon,check} = \frac{q_{total}}{L \cdot 60 \cdot \rho_{Ar,stp}}$$

$$\rho_{Ar,stp} = \rho['Argon', T = 519.67, P = 14.7]$$

SOLUTION

Unit Settings: [R]/[psia]/[lbm]/[degrees]

A = 82.79 [ft^2]
α_{air} = 0.9032 [ft^2/hr]
A_{mli} = 82.79 [ft^2]
β = 0.001806 [1/R]
C = 377
$convection_{ratio}$ = 8.439
$C_{p,air}$ = 0.2405 [Btu/lbm-R]
D_1 = 0.4413 [ft]
$D_{1,inches}$ = 5.295 [in]
D_{22} = 0.1979 [in]
$D_{22,inches}$ = 2.375 [in]
D_i = 0.2635 [ft]
D_{mli} = 0.2635 [ft]
$D_{mli,inches}$ = 3.162 [in]
D_o = 0.4413 [ft]
ε_1 = 1
ε_{22} = 1
ε_{mli} = 0.05
F = 1
gravity = 4.173E+08 [ft/hr^2]
G_i = 9.715 [ ]
k_{air} = 0.01557 [Btu / (hr*ft*R)]
$k_{effective}$ = 0.1314 [Btu / (hr*ft*R)]
L = 60.68 [Btu/lbm]
L_{gap} = 0.08886 [ft]
$L_{gap,inches}$ = 1.066 [in]
$L_{gap,mli}$ = 0.00164 [ft]
L_{pipe} = 100.00 [ft]
M = 39.95
$mli_{thickness}$ = 0.03281 [ft]
ν_{air} = 0.6004 [ft^2/hr]
P = 126.2 [psia]
Pr_{air} = 0.6648 [ ]
$Psat$ = 126.2 [psia]
$P_{crticalcargon}$ = 705.3 [psia]
$qcond_{1011}$ = 12214 [Btu/hr]
$qcond_{1112}$ = 12216 [Btu/hr]
$qcond_{1213}$ = 12217 [Btu/hr]
$qcond_{1314}$ = 12219 [Btu/hr]
$qcond_{1415}$ = 12220 [Btu/hr]
$qcond_{1516}$ = 12221 [Btu/hr]
$qcond_{1617}$ = 12222 [Btu/hr]
$qcond_{1718}$ = 12223 [Btu/hr]
$qcond_{1819}$ = 12223 [Btu/hr]
$qcond_{1920}$ = 12224 [Btu/hr]
$qcond_{2021}$ = 12225 [Btu/hr]
$qcond_{2122}$ = 12223 [Btu/hr]
$qcond_{23}$ = 12198 [Btu/hr]
$qcond_{34}$ = 12200 [Btu/hr]
$qcond_{45}$ = 12203 [Btu/hr]
$qcond_{56}$ = 12205 [Btu/hr]
$qcond_{67}$ = 12207 [Btu/hr]
$qcond_{78}$ = 12209 [Btu/hr]
$qcond_{89}$ = 12211 [Btu/hr]
$qcond_{910}$ = 12213 [Btu/hr]
$qconv_{12}$ = 11869 [Btu/hr]
$qrad_{1011}$ = 12.87 [Btu/hr]
$qrad_{1112}$ = 11.37 [Btu/hr]
$qrad_{12}$ = 358.470 [Btu/hr]
$qrad_{1213}$ = 9.995 [Btu/hr]
$qrad_{1314}$ = 8.734 [Btu/hr]
$qrad_{1415}$ = 7.584 [Btu/hr]
$qrad_{1516}$ = 6.539 [Btu/hr]
$qrad_{1617}$ = 5.595 [Btu/hr]
$qrad_{1718}$ = 4.746 [Btu/hr]
$qrad_{1819}$ = 3.988 [Btu/hr]
$qrad_{1920}$ = 3.315 [Btu/hr]
$qrad_{2021}$ = 2.722 [Btu/hr]
$qrad_{2122}$ = 4.299 [Btu/hr]
$qrad_{23}$ = 29.77 [Btu/hr]
$qrad_{34}$ = 27.13 [Btu/hr]
$qrad_{45}$ = 24.65 [Btu/hr]
$qrad_{56}$ = 22.33 [Btu/hr]
$qrad_{67}$ = 20.16 [Btu/hr]
$qrad_{78}$ = 18.13 [Btu/hr]
$qrad_{89}$ = 16.24 [Btu/hr]
$qrad_{910}$ = 14.49 [Btu/hr]
Q_a = 20.38 [SCFM]
$q_{argon,check}$ = 31.87 [SCFM]
q_{total} = 12227.316 [Btu/hr]
$q_{total,W}$ = 3583 [W]
R = 38.68

Ra_{cstar} = 524327	Ra_L = 72269 [ ]
ρ_{air} = 0.07167 [lb_m/ft^3]	$\rho_{Ar,stp}$ = 0.1054 [lb_m/ft^3]
σ = 1.714E-09 [Btu / (hr*ft^2 * R$^{4)}$]	T = 205.7 [R]
T_1 = 590.7 [R]	T_{10} = 392.3 [R]
T_{11} = 376.7 [R]	T_{12} = 361.2 [R]
T_{13} = 345.7 [R]	T_{14} = 330.1 [R]
T_{15} = 314.6 [R]	T_{16} = 299 [R]
T_{17} = 283.4 [R]	T_{18} = 267.9 [R]
T_{19} = 252.3 [R]	T_2 = 516.563 [R]
T_{20} = 236.78 [R]	T_{21} = 221.2 [R]
T_{22} = 205.7 [R]	T_3 = 501 [R]
T_4 = 485.5 [R]	T_5 = 470 [R]
T_6 = 454.5 [R]	T_7 = 438.9 [R]
T_8 = 423.4 [R]	T_9 = 407.8 [R]
$T_{ambient}$ = 590.7 [R]	T_f = 553.6 [R]
T_i = 516.6 [R]	T_o = 590.670 [R]
U = 0.3836 [Btu/hr-ft^2-R]	V = 0.3685 [ft^3/lb_m]
Z = 0.8418 [ ]	

54 potential unit problems were detected.

EES suggested units (shown in purple) for D_22 D_i T T_f T_i .

Appendix G
Welder Qualifications

Fermilab — Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record

In accordance with WPS AMI/Orbital 003

Date 3/10/2010

Revision:	**Revision Date :**	**Remarks:**

Welders Name:	*Leonard Harbacek*	**Fermi ID#**	*12261N*	**Weld Stamp**	*8*
WPS Number:	*AMI/Orbital 003*	**Test Coupon**	~~Production Weld~~ *N/A*		
Welding Process/Type	*GTAW/Orbital*	*Automatic*			
Type of Joint Welded:	*Pipe Groove Weld*	**Joint Types Qualified:**	*Groove and Fillet Welds*		
Base Metals Welded:	*ASTM A269-04 316/316L*	*S8, Group 1*			

Welder Variables (QW-350)	Actual Variables Used	Range Qualified
AWS Classification:		
Filler Metal Specification (SFA)	*N/A*	
Filler Metal F-No.	*N/A*	
Filler Metal Product Form	*N/A*	
Consumable Insert	*No Insert Used*	*Without Insert*
P- or S- Number to P- or S- Number:	*S8, Group 1*	*All Qualified Materials*
Base Metal Thickness (inches):	*.049”*	*WPS Limits*
Pipe Diameter (inches):	*.500” Ø*	*Unlimited*
Deposit Thickness (inches)	*.049”*	*WPS Limits*
Welding Position/Progression	*5G*	*All*
Backing Gas	*Argon 99.9%*	
GTAW-Current/Polarity	*DCEN/Pulsing*	

Machine Welding Variables (QW-360)	Actual Variables	Range Qualified
Direct/Remote Visual Control	*N/A*	*N/A*
Automatic Voltage Control	*N/A*	*N/A*
Automatic Joint Tracking	*N/A*	*N/A*
Welding Position	*N/A*	*N/A*
Consumable Insert	*N/A*	*N/A*
Backing	*N/A*	*N/A*
Single/Multiple Pass Per Side	*N/A*	*N/A*

Fillet Welds: *Qualified to make fillet welds of any size on all base material thickness and pipe diameters of any size.*
Notes:

ASME IX Guided Bend Test (QW-160)				**ASME IX Weld Tensil (QW 150)**		
Face Bend #1	*Acceptable*	**Root Bend #1**	*Acceptable*	**Specimen 001**	*Ductile-WM*	**Test Reference No.**
Face Bend #2	*Acceptable*	**Root Bend #2**	*Acceptable*	**Specimen 002**	*Ductile WM*	*T002962*

Visual examination results: *Visual exam satisfactory per QW-302.4 and QW-194*

Radiographic test results: *N/A*	**Radiographic tests conducted by:**	*N/A*

Mechanical Tests Conducted by: *Exova Materials Testing Laboratory*

Welding of Test Coupon conducted by: *Fermi National Accelerator Laboratory*	**Verification Number**	*2012010-3RH*

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Fermi National Accelerator Laboratory ______________________________

Authorized Representative Date

Fermilab — Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record *In accordance with WPS AMI/Orbital 001*		**Date** *3/10/2010***
Revision:	**Revision Date :**	**Remarks:**

Welders Name:	*Leonard Harbacek*	**Fermi ID#**	*12261N*	**Weld Stamp**	*8*
WPS Number:	*AMI/Orbital 001*	**Test Coupon**	~~**Production Weld**~~ *N/A*		
Welding Process/Type	*GTAW/Orbital*	*Automatic*			
Type of Joint Welded:	*Pipe Groove Weld*	**Joint Types Qualified:**	*Groove and Fillet Welds*		
Base Metals Welded:	*ASTM A269 316/316L*	*S8, Group 1*			

Welder Variables (QW-350)	Actual Variables Used	Range Qualified
AWS Classification:		
Filler Metal Specification (SFA)	*N/A*	*"See Notes"*
Filler Metal F-No.	*N/A*	
Filler Metal Product Form	*N/A*	
Consumable Insert	*No Insert Used*	*Without Insert*
P- or S- Number to P- or S- Number:	*S8, Group 1*	*All Qualified Materials*
Base Metal Thickness (inches):	*.035"*	*WPS Limits*
Pipe Diameter (inches):	*.250" Ø*	*Unlimited*
Deposit Thickness (inches)	*.035"*	*WPS Limits*
Welding Position/Progression	*5G*	*All*
Backing Gas	*Argon 99.9%*	
GTAW-Current/Polarity	*DCEN/Pulsing*	

Machine Welding Variables (QW-360)	Actual Variables	Range Qualified
Direct/Remote Visual Control	*N/A*	*N/A*
Automatic Voltage Control	*N/A*	*N/A*
Automatic Joint Tracking	*N/A*	*N/A*
Welding Position	*N/A*	*N/A*
Consumable Insert	*N/A*	*N/A*
Backing	*N/A*	*N/A*
Single/Multiple Pass Per Side	*N/A*	*N/A*

Fillet Welds: *Qualified to make fillet welds of any size on all base material thickness and pipe diameters of any size.*
Notes: ***Qualified for All Qualified Welding Procedures using GTAW/Automatic Welding Process***

ASME IX Guided Bend Test (QW-160)				ASME IX Weld Tensil (QW 150)		
Face Bend #1	*Acceptable*	**Root Bend #1**	*Acceptable*	**Specimen 001**	*Ductile WM*	**Test Reference No.**
Face Bend #2	*Acceptable*	**Root Bend #2**	*Acceptable*	**Specimen 002**	*Ductile WM*	*T002966*

Visual examination results: *Visual exam satisfactory per QW-302.4 and QW-194*

Radiographic test results: *N/A* | **Radiographic tests conducted by:** *N/A*

Mechanical Tests Conducted by: *Exova Materials Testing Laboratory*

Welding of Test Coupon conducted by: *Fermi National Accelerator Laboratory* | **Verification Number** *2102010-2RH*

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Fermi National Accelerator Laboratory Roger Geller — Authorized Representative   3/10/2010 — Date

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Welder Qualification Test Record

Welder's Name Leonard Harbacek Ident No. 122261 Date 03/19/99

Welding Process GTAW Type Manual

Test in Accordance With WPS # ES-155003 Root Open

Material Specification SA 53-B To Material Specification SA 53-B

P-No 1 To P-No 1 Thickness .280" Diam 6"

Filler Metal Specification SFA A5.18 Classification ER-70S-2 F-No 6

Thickness Deposited .280

Backing Argon Gas Shielding Argon

Position 6-G Progression Upward

Electrical Characteristics: Current DC Polarity Straight

Thickness Qualified .560" Max Diameter Qualified 2-7/8" O.D. and over

GUIDED BEND TEST RESULTS

Specimen No	Type	Figure	Results
1	Face	QW-462.3a	Acceptable
2	Face	QW-462.3a	Acceptable
3	Root	QW-462.3a	Acceptable
4	Root	QW-462.3a	Acceptable

Test Conducted By IFR Engineering Test No. 008-09-01 Date 3/19/99

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

By: [signature]

Date: 4/22/99

FERMILAB

COPY

Welder Qualification Test Record

Welder's Name Leonard Harbacek Ident No. 122261 Date 03/19/99

Welding Process SMAW Type Manual

Test in Accordance With WPS # ES-155000 Root Open

Material Specification SA 53-B To Material Specification SA 53-B

P-No 1 To P-No 1 Thickness .280" Diam 6"

Filler Metal Specification SFA A5.1 Classification E6010/E7018 F-No F3/F4

Thickness Deposited .280

Backing None Gas Shielding N/A

Position 6-G Progression Upward

Electrical Characteristics: Current DC Polarity Reverse

Thickness Qualified .560" Max Diameter Qualified 2-7/8" O.D. and over

GUIDED BEND TEST RESULTS

Specimen No	Type	Figure	Results
1	Face	QW-462.3a	Acceptable
2	Face	QW-462.3a	Acceptable
3	Root	QW-462.3a	Acceptable
4	Root	QW-462.3a	Acceptable

Test Conducted By IFR Engineering Test No. 008-09-01 Date 3/19/99

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

By: [signature] 4/22/99

Date: 4/22/99

FERMILAB

COPY

Welder Qualification Test Record

Welder's Name Leonard Harbacek Ident No. 122261 Date 03/19/99

Welding Process SMAW Type Manual

Test in Accordance With WPS # ES-155000 Root Open

Material Specification SA 53-B To Material Specification SA 53-B

P-No 1 To P-No 1 Thickness .280" Diam 6"

Filler Metal Specification SFA A5.1 Classification E6010/E7018 F-No F3/F4

Thickness Deposited .280

Backing None Gas Shielding N/A

Position 6-G Progression Upward

Electrical Characteristics: Current DC Polarity Reverse

Thickness Qualified .560" Max Diameter Qualified 2-7/8" O.D. and over

GUIDED BEND TEST RESULTS

Specimen No	Type	Figure	Results
1	Face	QW-462.3a	Acceptable
2	Face	QW-462.3a	Acceptable
3	Root	QW-462.3a	Acceptable
4	Root	QW-462.3a	Acceptable

Test Conducted By IFR Engineering Test No. 008-09-01 Date 3/19/99

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

By: Roger Ellen 4/22/99

Date: 4/22/99

Fermilab Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record *In accordance with WPS Cajon/Orbital 001*	**Date** *3/11/2010***

Revision:	**Revision Date :**	**Remarks:**

Welders Name:	*Leonard Harbacek*	**Fermi ID#**	*12261N*	**Weld Stamp**	*8*
WPS Number:	*Cajon/Orbital 001*	**Test Coupon**	~~**Production Weld**~~ *N/A*		
Welding Process/Type	*GTAW/Orbital*	*Automatic*			
Type of Joint Welded:	*Pipe Groove Weld*	**Joint Types Qualified:**	*Groove and Fillet Welds*		
Base Metals Welded:	*SA249 304/304L*	*P8, Group 1*			

Welder Variables (QW-350)	**Actual Variables Used**	**Range Qualified**
AWS Classification:		
Filler Metal Specification (SFA)	*N/A*	*"See Notes"*
Filler Metal F-No.	*N/A*	
Filler Metal Product Form	*N/A*	
Consumable Insert	*No Insert Used*	*Without Insert*
P- or S- Number to P- or S- Number:	*P8, Group 1*	*All Qualified Materials*
Base Metal Thickness (inches):	*.035"*	*WPS Limits*
Pipe Diameter (inches):	*.250" Ø*	*Unlimited*
Deposit Thickness (inches)	*.035"*	*WPS Limits*
Welding Position/Progression	*5G*	*All*
Backing Gas	*Argon 99.9%*	
GTAW-Current/Polarity	*DCEN/Pulsing*	

Machine Welding Variables (QW-360)	**Actual Variables**	**Range Qualified**
Direct/Remote Visual Control	*N/A*	*N/A*
Automatic Voltage Control	*N/A*	*N/A*
Automatic Joint Tracking	*N/A*	*N/A*
Welding Position	*N/A*	*N/A*
Consumable Insert	*N/A*	*N/A*
Backing	*N/A*	*N/A*
Single/Multiple Pass Per Side	*N/A*	*N/A*

Fillet Welds: *Qualified to make fillet welds of any size on all base material thickness and pipe diameters of any size.*
Notes: *Qualified for all Qualified Welding Procedures using Automatic GTAW Welding Process.*

ASME IX Guided Bend Test (QW-160)				**ASME IX Weld Tensil (QW 150)**		
Face Bend #1	*Acceptable*	**Root Bend #1**	*Acceptable*	**Specimen 001**	*Ductile-BM*	**Test Reference No.**
Face Bend #2	*Acceptable*	**Root Bend #2**	*Acceptable*	**Specimen 002**	*Ductile BM*	*T000499*

Visual examination results: *Visual exam satisfactory per QW-302.4 and QW-194*

Radiographic test results: *N/A*	**Radiographic tests conducted by:**	*N/A*

Mechanical Tests Conducted by: *Exova Materials Testing Laboratory*

Welding of Test Coupon conducted by: *Fermi National Accelerator Laboratory*	**Verification Number**	*2102010-2RH*

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Fermi National Accelerator Laboratory ______________________________

Authorized Representative   Date

Fermilab **Fermi National Accelerator Laboratory**

Technical Division-Machine Shop

Welder Performance Qualification Record

In accordance with WPS Cajon/Orbital 003

Date 3/11/2010

Revision:	Revision Date :	Remarks:

Welders Name:	Leonard Harbacek	**Fermi ID#**	12261N	**Weld Stamp**	8
WPS Number:	Cajon/Orbital 003	**Test Coupon**	~~Production Weld~~ N/A		
Welding Process/Type	GTAW/Orbital	Automatic			
Type of Joint Welded:	Pipe Groove Weld	**Joint Types Qualified:**	Groove and Fillet Welds		
Base Metals Welded:	ASTM A269 316/316L	S8, Group 1			

Welder Variables (QW-350)	Actual Variables Used	Range Qualified
AWS Classification:		
Filler Metal Specification (SFA)	N/A	
Filler Metal F-No.	N/A	
Filler Metal Product Form	N/A	
Consumable Insert	No Insert Used	Without Insert
P- or S- Number to P- or S- Number:	S8, Group 1	All Qualified Materials
Base Metal Thickness (inches):	.049"	WPS Limits
Pipe Diameter (inches):	.500"Ø	Unlimited
Deposit Thickness (inches)	.049"	WPS Limits
Welding Position/Progression	5G	All
Backing Gas	Argon 99.9%	
GTAW-Current/Polarity	DCEN/Pulsing	

Machine Welding Variables (QW-360)	Actual Variables	Range Qualified
Direct/Remote Visual Control	N/A	N/A
Automatic Voltage Control	N/A	N/A
Automatic Joint Tracking	N/A	N/A
Welding Position	N/A	N/A
Consumable Insert	N/A	N/A
Backing	N/A	N/A
Single/Multiple Pass Per Side	N/A	N/A

Fillet Welds: *Qualified to make fillet welds of any size on all base material thickness and pipe diameters of any size.*
Notes: ***Qualified for all Qualified Welding Procedures using Automatic GTAW Process***

ASME IX Guided Bend Test (QW-160)				ASME IX Weld Tensil (QW 150)		
Face Bend #1	Acceptable	**Root Bend #1**	Acceptable	**Specimen 001**	Ductile HAZ	**Test Reference No.**
Face Bend #2	Acceptable	**Root Bend #2**	Acceptable	**Specimen 002**	Ductile WM	T002964

Visual examination results: *Visual exam satisfactory per QW-302.4 and QW-194*

Radiographic test results: N/A	**Radiographic tests conducted by:**	N/A

Mechanical Tests Conducted by: *Exova Materials Testing Laboratory*

Welding of Test Coupon conducted by: *Fermi National Accelerator Laboratory*	**Verification Number**	2012010-3RH

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Fermi National Accelerator Laboratory [signature] Authorized Representative — 3/11/2010 Date

Fermilab *Fermi National Accelerator Laboratory*

Technical Division-Machine Shop

Welder Performance Qualification Record

In accordance with WPS Cajon/Orbital 002

Date: *3/12/2010***

Revision:	Revision Date :	Remarks:

Welders Name:	*Leonard Harbacek*	**Fermi ID#**	*12261N*	**Weld Stamp**	**8**
WPS Number:	*Fermi Cajon/Orbital 002*	**Test Coupon**	~~**Production Weld**~~ *N/A*		
Welding Process/Type	*GTAW/Orbital*	*Automatic*			
Type of Joint Welded:	*Pipe Groove Weld*	**Joint Types Qualified:**	*Groove and Fillet Welds*		
Base Metals Welded:	*P8, Group 1 to P8, Group 1*				

Welder Variables (QW-350)	**Actual Variables Used**	**Range Qualified**
AWS Classification:		
Filler Metal Specification (SFA)	*N/A*	*"See Notes for Qualified Range"*
Filler Metal F-No.	*N/A*	
Filler Metal Product Form	*N/A*	
Consumable Insert	*No Insert Used*	*Without Insert*
P- or S- Number to P- or S- Number:	*P8, Group 1*	*All Qualified Materials*
Base Metal Thickness (inches):	*.035*	*WPS Limits*
Pipe Diameter (inches):	*.500*	*Unlimited*
Deposit Thickness (inches)	*.035*	*WPS Limits*
Welding Position/Progression	*5G*	*All*
Backing Gas	*Argon 99.9%*	
GTAW-Current/Polarity	*DCEN/Pulsing*	

Machine Welding Variables (QW-360)	**Actual Variables**	**Range Qualified**
Direct/Remote Visual Control	*N/A*	*N/A*
Automatic Voltage Control	*N/A*	*N/A*
Automatic Joint Tracking	*N/A*	*N/A*
Welding Position	*N/A*	*N/A*
Consumable Insert	*N/A*	*N/A*
Backing	*N/A*	*N/A*
Single/Multiple Pass Per Side	*N/A*	*N/A*

Fillet Welds: *Qualified to make fillet welds of any size on all base material thickness and pipe diameters of any size.*
Notes: ***Qualified for all Qualified Welding Procedures using GTAW/Automatic Welding Process***

ASME IX Guided Bend Test (QW-160)				**ASME IX Weld Tensil (QW 150)**		
Face Bend #1	*Acceptable*	**Root Bend #1**	*Acceptable*	**Specimen 001**	*Ductile-BM*	**Test Reference No.**
Face Bend #2	*Acceptable*	**Root Bend #2**	*Acceptable*	**Specimen 002**	*Ductil-BM*	*T 000500*

Visual examination results: *Visual exam satisfactory per QW-302.4 and QW-194*

Radiographic test results: *N/A*	**Radiographic tests conducted by:**	*N/A*

Mechanical Tests Conducted by: *Exova Materials Testing Laboratory*

Welding of Test Coupon conducted by: *Fermi National Accelerator Laboratory*	**Verification Number**	*12282009-2RH*

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Fermi National Accelerator Laboratory Roger Ellillar — Authorized Representative 3/12/2010 — Date

Fermilab

Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record

Welder's Name	*Ryan Mahoney*				**FNAL #**	*15470N*	**ASME #**	*W-2*	
Welding Process:	**1st**	*GTAW*	Type	*Manual*	**2nd**		Type		
Performed in accordance with:	*Fermi WPS SS-3,R4*								

Joint:	~~Fillet:~~		~~Production Weld~~	*Test Coupon*		
Groove:	~~Double Welded:~~	~~Yes~~	No			
	Single Welded:	~~Metal Fused~~	~~Metal Non-Fused~~	~~Non-Metal~~	*Open Root*	~~Consumable Insert~~
		~~With Solid Backing~~	*Without Solid Backing*			

Base Metal:	Specification:	*SA 312, Gr 304*	TO	*SA 312, Gr 304*	ASME P #8	TO	ASME P # 8
~~**Plate**~~	**Pipe**				~~**Tube**~~		
Actual Thickness:	Nominal Diameter: 4	Actual Diameter: *4/5"*			Overall Diameter:		
Qualified Range:	Wt/Schedule: *Sch. 80*	Qualified Thickness Range: *0-0.674*			Wall:		
	Actual Thickness: *0.337*	Qualified Diameter Range: *2.875" minimum*			Qualified Thickness Range:		
					Qualified Diameter Range:		

Filler:	**1st Process**		**2nd Process**	
	Specification: *SFA 5.9*	Class: *ER 308/308L*	Specification:	Class:
	Diameter(s): *1/16"Ø, 3/32"Ø*		Diameter(s):	
	F #: *6*		F #:	
	Deposit Thickness: *0.0337*	Range Qualification: *0-0.674"*	Deposit Thickness:	Range Qualification:

Welding Position: *6G*	If Vertical: *Upward* ~~Down~~				
Gas (Type & Composition:	Shielding: *Argon 99.9%*		Root Side Backing	*Argon 99.9%*	
Electrical Characteristics	Type Current	~~AC~~	~~DCEP~~	*DCEN*	
	Transfer GMAW	~~Spray~~	~~Globular~~	~~Pulse~~	~~Short Circuit~~

For Information Only		**Machine Welding**		
Filler Metal Trade Name:		Control:	☐ Visual	☐ Remote Visual
SAW Flux Trade Name:		Arc Voltage Control:	☐ Auto	☐ Other:
Shielding Gas Trade Name:		Joint Tracking:	☐ Yes	☐ No

Visual Inspection					
Appearance:	*Satisfactory*	Undercut:		Piping Porosity:	

Guided Bend Test					
Type and Figure	Results	Type and Figure	Results	Type and Figure	Results
Test Conducted by:			Lab Test #:		Date:

Radiographic Test			
Results: Satisfactory	Per ASME IX-2007 and AWS D1.1-06		
Radiographer: *Alloyweld Inspection Co., Inc.*	Examiner: *Jennifer Anaya-Level II*	*Register #5615*	Date: *6/18/2010*

Fillet Weld Test Results				
Fracture Test:(Location, Nature, and size of Crack or Tear in Specimen)				
Length of Weld:	Length of Defect:		Percent of Defect	
Macro Test: Fusion				
Appearance: Fillet Size	inch X	inch	☐ Convex	☐ Concave
Test Conducted by:	Lab Test #:			

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of **ASME IX-2007 & AWS D1.1-06** ***Fermi National Accelerator Laboratory***	
By:	Date:

Fermilab **Fermi National Accelerator Laboratory**

Technical Division-Machine Shop

Welder Performance Qualification Record

Welder's Name	Ryan Mahoney			FNAL #	15470N	ASME #	W-2
Welding Process:	1st	GTAW	Type	Manual	2nd	Type	
Performed in accordance with:	Fermi WPS SS-3,R4						

Joint:	~~Fillet:~~		~~Production Weld~~	Test Coupon		
Groove:	~~Double Welded:~~	~~Yes~~	No			
	Single Welded:	~~Metal Fused~~	~~Metal Non-Fused~~	~~Non-Metal~~	Open Root	~~Consumable Insert~~
		~~With Solid Backing~~	Without Solid Backing			

Base Metal:	Specification: SA 312, Gr 304	TO	SA 312, Gr 304	ASME P #8	TO ASME P # 8
~~Plate~~	Pipe			~~Tube~~	
Actual Thickness:	Nominal Diameter: 4	Actual Diameter: 4/5"		Overall Diameter:	
Qualified Range:	Wt/Schedule: Sch. 80	Qualified Thickness Range: 0-0.674		Wall:	
	Actual Thickness: 0.337	Qualified Diameter Range: 2.875" minimum		Qualified Thickness Range:	
				Qualified Diameter Range:	

Filler:	1st Process		2nd Process	
	Specification: SFA 5.9	Class: ER 308/308L	Specification:	Class:
	Diameter(s): 1/16"Ø, 3/32"Ø		Diameter(s):	
	F #: 6		F #:	
	Deposit Thickness: 0.0337	Range Qualification: 0-0.674"	Deposit Thickness:	Range Qualification:

Welding Position: 6G	If Vertical: Upward ~~Down~~				
Gas (Type & Composition:	Shielding: Argon 99.9%		Root Side Backing	Argon 99.9%	
Electrical Characteristics	Type Current	~~AC~~	~~DCEP~~	DCEN	
	Transfer GMAW	~~Spray~~	~~Globular~~	~~Pulse~~	~~Short Circuit~~

For Information Only		Machine Welding		
Filler Metal Trade Name:		Control:	☐ Visual	☐ Remote Visual
SAW Flux Trade Name:		Arc Voltage Control:	☐ Auto	☐ Other:
Shielding Gas Trade Name:		Joint Tracking:	☐ Yes	☐ No

Visual Inspection					
Appearance:	Satisfactory	Undercut:		Piping Porosity:	

Guided Bend Test					
Type and Figure	Results	Type and Figure	Results	Type and Figure	Results
Test Conducted by:			Lab Test #:		Date:

Radiographic Test			
Results: Satisfactory	Per ASME IX-2007 and AWS D1.1-06		
Radiographer: Alloyweld Inspection Co., Inc.	Examiner: Jennifer Anaya-Level II	Register # 5615	Date: 6/18/2010

Fillet Weld Test Results			
Fracture Test:(Location, Nature, and size of Crack or Tear in Specimen)			
Length of Weld:	Length of Defect:	Percent of Defect	
Macro Test: Fusion			
Appearance: Fillet Size inch X	inch	☐ Convex	☐ Concave
Test Conducted by:	Lab Test #:		

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of ASME IX-2007 *Fermi National Accelerator Laboratory*

By:	Date:
[signature]	6/18/2010

Fermilab

Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record

Welder's Name	Ryan Mahoney			FNAL #	15470N	ASME #	W-2
Welding Process:	1st	GTAW	Type	Manual	2nd		Type
Performed in accordance with:	Fermi WPS SS-3,R4						

Joint:	~~Fillet:~~	~~Production Weld~~		Test Coupon	
Groove:	~~Double Welded:~~	~~Yes~~	No		
	Single Welded:	~~Metal Fused~~	~~Metal Non-Fused~~	~~Non-Metal~~	Open Root	~~Consumable Insert~~
		~~With Solid Backing~~	Without Solid Backing		

Base Metal:	Specification:	SA 312, Gr 304	TO	SA 312, Gr 304	ASME P #8	TO ASME P # 8
~~Plate~~	Pipe				~~Tube~~	
Actual Thickness:	Nominal Diameter: 4		Actual Diameter: 4/5"		Overall Diameter:	
Qualified Range:	Wt/Schedule: Sch. 80		Qualified Thickness Range: 0-0.674		Wall:	
	Actual Thickness: 0.337		Qualified Diameter Range: 2.875" minimum		Qualified Thickness Range:	
					Qualified Diameter Range:	

Filler:	1st Process		2nd Process	
	Specification: SFA 5.9	Class: ER 308/308L	Specification:	Class:
	Diameter(s): 1/16"Ø, 3/32"Ø		Diameter(s):	
	F #: 6		F #:	
	Deposit Thickness: 0.0337	Range Qualification: 0-0.674"	Deposit Thickness:	Range Qualification:

Welding Position: 6G	If Vertical: Upward ~~Down~~				
Gas (Type & Composition:	Shielding: Argon 99.9%		Root Side Backing	Argon 99.9%	
Electrical Characteristics	Type Current	~~AC~~	~~DCEP~~	DCEN	
	Transfer GMAW	~~Spray~~	~~Globular~~	~~Pulse~~	~~Short Circuit~~

For Information Only		Machine Welding		
Filler Metal Trade Name:		Control:	☐ Visual	☐ Remote Visual
SAW Flux Trade Name:		Arc Voltage Control:	☐ Auto	☐ Other:
Shielding Gas Trade Name:		Joint Tracking:	☐ Yes	☐ No

Visual Inspection					
Appearance:	Satisfactory	Undercut:		Piping Porosity:	

Guided Bend Test					
Type and Figure	Results	Type and Figure	Results	Type and Figure	Results
Test Conducted by:			Lab Test #:		Date:

Radiographic Test			
Results: Satisfactory	Per ASME IX-2007 and AWS D1.1-06		
Radiographer: Alloyweld Inspection Co., Inc.	Examiner: Jennifer Anaya-Level II	Register # 5615	Date: 6/18/2010

Fillet Weld Test Results			
Fracture Test:(Location, Nature, and size of Crack or Tear in Specimen)			
Length of Weld:	Length of Defect:	Percent of Defect	
Macro Test: Fusion			
Appearance: Fillet Size inch X inch		☐ Convex	☐ Concave
Test Conducted by:	Lab Test #:		

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of ASME IX-2007 *Fermi National Accelerator Laboratory*

By: Roger C. Hiller	Date: 6/18/2010

Fermilab

Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record

Welder's Name	Ryan Mahoney			FNAL #	15470N		ASME #	W-2
Welding Process:	1st	GTAW	Type	Manual	2nd		Type	
Performed in accordance with:	Fermi WPS-SS-8-001							

Joint:	~~Fillet:~~		~~Production Weld~~	Test Coupon		
Groove:	~~Double Welded:~~	~~Yes~~	No			
	Single Welded:	~~Metal Fused~~	~~Metal Non Fused~~	~~Non Metal~~	Open Root	Consumable Insert
		~~With Solid Backing~~	Without Solid Backing			

Base Metal:	Specification: SA 213, Type 304/304L	TO	SA 213, Type 304/304L	ASME P #8, Gp 1	TO	ASME P # 8, Gp 1
Plate	Pipe			Tube		
Actual Thickness:	Nominal Diameter:		Actual Diameter	Overall Diameter: 0.250"		
Qualified Range:	Wt/Schedule:	Qualified Thickness Range		Wall: 0.035"		
	Actual Thickness	Qualified Diameter Range: .		Qualified Thickness Range: 0.070" Maximum		
				Qualified Diameter Range: 0.250" Minimum		

Filler:	1st Process		2nd Process	
	Specification: 5.9	Class: 308/308L	Specification:	Class:
	Diameter(s): .035, .045, 1/16		Diameter(s):	
	F #: 6		F #:	
	Deposit Thickness: 0.035	Range Qualification: 0.070 Maximum	Deposit Thickness:	Range Qualification:

Welding Position: 6G	If Vertical: Uphill ~~Down~~				
Gas (Type & Composition:	Shielding: Argon 99.9%		Root Side Backing - Argon 99.9%		
Electrical Characteristics	Type Current	~~AC~~	~~DCEP~~	DCEN	
	~~Transfer GMAW~~	~~Spray~~	~~Globular~~	~~Pulse~~	~~Short Circuit~~

Visual Inspection					
Appearance:	Satisfactory	Undercut:	None	Piping Porosity:	None

Guided Bend Test					
Type and Figure	Results	Type and Figure	Results	Type and Figure	Results
Test Conducted by:			Lab Test #:		Date:

Radiographic Test			
Results: Satisfactory	Per ASME IX-2007		
Radiographer: Alloyweld Inspection Co., Inc.	Examiner: Jennifer Anaya-Level II	Register # 5615	Date: 6/18/2010

Fillet Weld Test Results			
Fracture Test: (Location, Nature, and size of Crack or Tear in Specimen)			
Length of Weld:	Length of Defect:	Percent of Defect	
Macro Test: Fusion			
Appearance: Fillet Size inch X inch		☐ Convex	☐ Concave
Test Conducted by:	Lab Test #:		

Test Verified by: Roger Hiller, 00362N	Verification Report #5112010-2RH	
		Signature

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of ASME IX-2007 & AWS D1.1-06 **Fermi National Accelerator Laboratory**	
By: Roger Hiller 00362N Roger EHiller Authorized Representative	Date: 6/18/2010

Fermilab

Fermi National Accelerator Laboratory

Technical Division-Machine Shop

Welder Performance Qualification Record

Welder's Name	*Ryan Mahoney*				FNAL #	*15470N*	ASME #	*W-2*	
Welding Process:	1st	*GTAW*	Type	*Manual*	2nd		Type		
Performed in accordance with:	*Fermi WPS-SS-9-002*								

Joint:	~~Fillet:~~		~~Production Weld~~		*Test Coupon*	
Groove:	Double Welded:	~~Yes~~	*No*			
	Single Welded	~~Metal Fused~~	~~Metal Non-Fused~~	~~Non Metal~~	*Open Root*	Consumable Insert
		~~With Solid Backing~~	*Without Solid Backing*			

Base Metal:	Specification:	*SA 213, Type 304/304L*	TO	*SA 213, Type 304/304L*	*ASME P #8, Gp 1* TO *ASME P # 8, Gp 1*	
Plate	Pipe				Tube	
Actual Thickness:	Nominal Diameter:		Actual Diameter		Overall Diameter: *0.500"*	
Qualified Range:	Wt/Schedule:	Qualified Thickness Range			Wall: *0.095"*	
	Actual Thickness	Qualified Diameter Range			Qualified Thickness Range: *0.190" Maximum*	
					Qualified Diameter Range: *0.500" Minimum*	

Filler:	1st Process		2nd Process	
	Specification: *5.9*	Class: *308/308L*	Specification:	Class:
	Diameter(s): *.045, 1/16, 3/32*		Diameter(s):	
	F #: *6*		F #:	
	Deposit Thickness: *0.095*	Range Qualification: *0.190 Maximum*	Deposit Thickness:	Range Qualification:

Welding Position: *6G*	If Vertical: *Uphill* ~~Down~~				
Gas (Type & Composition:	Shielding: *Argon 99.9%*		Root Side Backing - *Argon 99.9%*		
Electrical Characteristics	Type Current	~~AC~~	~~DCEP~~	*DCEN*	
	~~Transfer GMAW~~	~~Spray~~	~~Globular~~	~~Pulse~~	~~Short Circuit~~

Visual Inspection					
Appearance:	*Satisfactory*	Undercut:	*None*	Piping Porosity:	*None*

Guided Bend Test					
Type and Figure	Results	Type and Figure	Results	Type and Figure	Results
Test Conducted by:			Lab Test #:		Date:

Radiographic Test			
Results: *Satisfactory*		Per ASME IX-2007 and AWS D1.1-06	
Radiographer: *Alloyweld Inspection Co., Inc.*	Examiner: *Jennifer Anaya-Level II*	Register # 5615	Date: *6/18/2010*

Fillet Weld Test Results				
Fracture Test: (Location, Nature, and size of Crack or Tear in Specimen)				
Length of Weld:	Length of Defect:		Percent of Defect	
Macro Test: Fusion				
Appearance: Fillet Size inch	X inch		☐ Convex	☐ Concave
Test Conducted by:	Lab Test #:			

Test Verified by: *Roger Hiller 00362N*	Verification Report #*5272010-2*	
		Signature

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of **ASME IX-2007 & AWS D1.1-06** ***Fermi National Accelerator Laboratory***	
By: Roger Hiller 00362N Roger Hiller Authorized Representative	Date: *6/18/2010*

Fermilab **Fermi National Accelerator Laboratory**

Technical Division-Machine Shop

Welder Performance Qualification Record *In accordance with WPS AMI/Orbital 002*		**Date** *4/07/2010***
Revision:	**Revision Date :**	**Remarks:**

Welders Name:	*Leonard Harbacek*	**Fermi ID#**	*12261N*	**Weld Stamp**	*8*
WPS Number:	*AMI/Orbital 002*	**Test Coupon**	~~**Production Weld**~~ *N/A*		
Welding Process/Type	*GTAW/Orbital*	*Automatic*			
Type of Joint Welded:	*Pipe Groove Weld*	**Joint Types Qualified:**	*Groove and Fillet Welds*		
Base Metals Welded:	*ASTM A269 (SA 249) Type 304/304L*	*P8, Group 1*			

Welder Variables (QW-350)	**Actual Variables Used**	**Range Qualified**
AWS Classification:		
Filler Metal Specification (SFA)	*N/A*	*"See Notes"*
Filler Metal F-No.	*N/A*	
Filler Metal Product Form	*N/A*	
Consumable Insert	*No Insert Used*	*Without Insert*
P- or S- Number to P- or S- Number:	*P8, Group 1*	*All Qualified Materials*
Base Metal Thickness (inches):	*.035"*	*WPS Limits*
Pipe Diameter (inches):	*.5000" Ø*	*Unlimited*
Deposit Thickness (inches)	*.035"*	*WPS Limits*
Welding Position/Progression	*5G*	*All*
Backing Gas	*Argon 99.9%*	
GTAW-Current/Polarity	*DCEN/Pulsing*	

Machine Welding Variables (QW-360)	**Actual Variables**	**Range Qualified**
Direct/Remote Visual Control	*N/A*	*N/A*
Automatic Voltage Control	*N/A*	*N/A*
Automatic Joint Tracking	*N/A*	*N/A*
Welding Position	*N/A*	*N/A*
Consumable Insert	*N/A*	*N/A*
Backing	*N/A*	*N/A*
Single/Multiple Pass Per Side	*N/A*	*N/A*

Fillet Welds: *Qualified to make fillet welds of any size on all base material thickness and pipe diameters of any size.*
Notes: ***Qualified for all Qualified Welding Procedures using GTAW/Automatic Welding Process***

ASME IX Guided Bend Test (QW-160)				**ASME IX Weld Tensil (QW 150)**		
Face Bend #1	*Acceptable*	**Root Bend #1**	*Acceptable*	**Specimen 001**	*Ductile-WM*	**Test Reference No.**
Face Bend #2	*Acceptable*	**Root Bend #2**	*Acceptable*	**Specimen 002**	*Ductile BM*	*T002963*

Visual examination results: *Visual exam satisfactory per QW-302.4 and QW-194*

Radiographic test results: *N/A* | **Radiographic tests conducted by:** *N/A*

Mechanical Tests Conducted by: *Exova Materials Testing Laboratory* *3/5/2010*

Welding of Test Coupon conducted by: *Fermi National Accelerator Laboratory* | **Verification Number** *2102010-1RH*

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Fermi National Accelerator Laboratory [signature] 4/07/2010

Authorized Representative — Date

Fermi National Accelerator Laboratory / Kirk Road and Pine Street / P.O. Box 500 / Batavia, IL 60510 / 630.840.3000 / www.fnal.gov / topquark@fnal.gov
Office of Science / U.S. Department of Energy / Managed by Universities Research Association, Inc.

Appendix H
Vacuum Relief Info

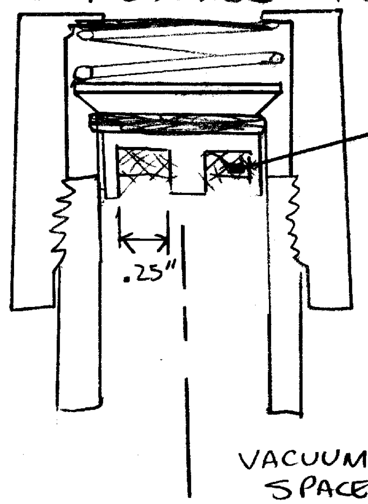
FERMILAB ENGINEERING NOTE	SECTION	PROJECT	SERIAL-CATEGORY	PAGE
	PPD/ETT DØ	VLPC CRYOGENICS	3823.113	7

SUBJECT	NAME	DATE	REVISION DATE
CVI PUMPOUT SONIC FLOW	RUSS RUCINSKI	2-12-99	

- CALCULATE MAXIMUM FLOW OUT OF CVI PUMPOUT,

FOR A STANDARD CVI V-1046-31 PUMP OUT THE POPPET CAN ONLY LIFT 0.25" TO EXPOSE 4 ~ 1/4" WIDE NOTCHES FOR RELIEVING.

SKETCH:
CVI PUMPOUT IN RELIEVING CONFIGURATION



AVAILABLE AREA
(4 SLOTS)(.25" WIDE)(.25" LIFT)
= 0.25 IN^2

MAX FLOW OF HELIUM IS SONIC FLOW.

FROM FIKE RUPTURE DISC SIZING BULLETIN, P. 10.

$$a = \frac{Q_s}{22772\, K C_2 P_0} \sqrt{(t+460)M} \qquad \text{WHERE } a = \text{AREA IN}^2$$

Q_s = STANDARD FLOW RATE SCFM (HELIUM IN OUR CASE)
K = 0.62 COEFF.
$C_2 = f(k = C_p/C_v = 1.66$ FOR HELIUM$) = .1048$
P_0 = RELIEVING PRESSURE SAY 30 PSIA.
$t = 60°F$ $M = 4$ MOLECULAR WT,

REARRANGING

$$Q_s = a\,(22772)\,K C_2 P_0 \frac{1}{\sqrt{(t+460)M}}$$

$$Q_s = (.25\,\text{in}^2)(22772)(.62)(.1048)(30\text{ PSIA}) \frac{1}{\sqrt{520 \cdot 4}}$$

Q_s = 243 scfm He.

CVI PUMP OUT TEST

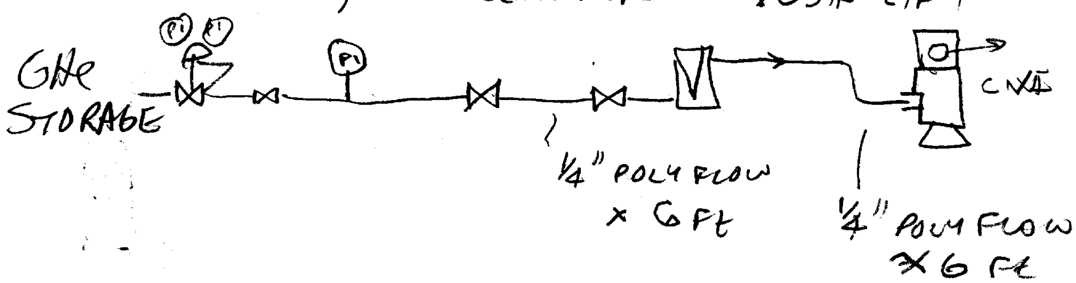
START TO RELIEVE @ 20 PSIG. START RISING FROM 0.0.

21 psi 0.04 IN RAISED UP

30 psi 0.08in RAISED UP RELIEVING HEAVILY.
RELIEVING OUT SIDE HOLES.

≈ 6 psi MOVES BACK TO 0.0" POSITION

23.2 PSI INLET, 2.0 scfh AIR .05 IN LIFT



FLOWMETER
DWYER RMA 0-5 SCFH AIR

P_{SUPPLY}	FI	CORRECTED FOR PRESS FI	LIFT	AREA = LIFT x 4 SLOTS x .25 IN
23.2	2.0 scfh AIR		0.05 IN	.05 IN^2
23.0	3.5 "		"	
24	4.2		0.07	.07 IN^2
24.2	5.0		.07"	.07 IN^2
30.0	>> 5.0		.08 IN	.08 IN^2

RESEAT ≈ 18 PSIG.

$$Q_2 = Q_1 \times \sqrt{\frac{1}{S.G.}} \times \sqrt{\frac{P_2}{P_1}} = 3.5 \text{ scfh AIR} \left(\frac{1}{.138} \times \sqrt{\frac{23+14.7}{14.7}} \right) = 15 \text{ scfh He.}$$

From: "Thomas J. Peterson " <tommy@fnal.gov>
Subject: **[Fwd: Vacuum relief cracking pressure]**
Date: February 7, 2007 4:59:08 PM CST
To: sanders@fnal.gov, tope@fnal.gov, degraff@fnal.gov, Arkadiy Klebaner <klebaner@fnal.gov>, Mayling Wong <mlwong@fnal.gov>
Cc: Tom Peterson <tommy@fnal.gov>

For the horizontal test cryostat, I believe that a 1 psig internal maximum pressure should be adequate.

The horizontal test cryostat has a standard Fermilab parallel plate relief valve. I forward below a measurement of lifting force, which showed that the cracking pressure and full-open pressure are both below 1 psid. Unless there were a very large flow rate and pressure drop through the opening (I don't have the venting calculations handy here right now), the vacuum vessel should never see over 1 psig. I do recall using a 3 psig maximum internal pressure on some earlier vessels, just to be on the very safe side regarding exit flow dynamics.

Regards,
Tom

-------- Original Message --------
Subject: Vacuum relief cracking pressure
Date: Mon, 22 Dec 2003 15:58:00 -0600
From: Tom Peterson <tommy@fnal.gov>
To: Jon Zbasnik <jzbasnik@lbl.gov>, Joseph Rasson <jerasson@lbl.gov>, Phil Pfund <pfund@fnal.gov>, Edward Bonnema <ecb.mtm-inc@worldnet.att.net>
CC: Jim Strait <strait@fnal.gov>, Tom Peterson <tommy@fnal.gov>

Several times in discussions, the question of exactly what is the "cracking" (start-to-open) pressure of the Femilab stock vacuum relief (MB-106391, rev. 1) has come up. I always just waved my hands and said it is very small. Here is a quantitative answer--the opening pressure is very small.

For a relief valve just removed from Fermilab's Tevatron stock, I measured a lifting force of 600 g (+/- 100 g) to just lift the valve slightly open, or 1.32 pounds force. The O-ring seal is 3 5/8 inches diameter, so internal pressure acts on an area of 10.32 square inches. Thus, the cracking pressure is 0.13 psid.

The flow area into the valve is 5.41 square inches (2 5/8 inner diameter), so the valve has to lift 0.66 inches to be fully open (radial outward flow area equal to inlet port area). For 0.66 inches of lift, I measure a force of about 3000 g, or 6.6 pounds force. For this force, one would need an internal pressure (neglecting dynamic flow effects) of 0.64 psid. Thus, the internal pressure for full-open is about 0.64 psid.

Regards,
Tom

Tom Peterson
Fermilab
630 840 4458